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Northern Mixedwood '89

Proceedings of a symposium held at Fort St. John, B.C. – September 12-14, 1989

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Northern Mixedwood '89

Proceedings of a symposium held at Fort St. John, B.C.

September 12-14, 1989

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FOREWORD

The Northern Mixedwood '89 Symposium, co-sponsored by Forestry Canada and the B.C. Ministry of Forests, under the Canada - British Columbia Forest Resource Development Agreement, was held from September 12 to 14, 1989 in Fort St. John, British Columbia. The main purpose of this Symposium was to provide forest practitioners with current operational insights and experiences to assist them in reaching solutions to management problems in mixedwood stands. Speakers from around the world deliberated on subjects including world demand, utilization, silviculture and integrated use planning.

Over 400 delegates were welcomed by Federal Forest Minister Frank Oberle and provincial Forest Minister Dave Parker. The formal program was chaired by Ken Pendergast, District Manager, Fort St. John District, B.C. Ministry of Forests.

The northern mixedwoods of Western Canada are the hottest investment area in the forest industry today. Managing this complex resource poses a challenge to all land managers. Northern Mixedwood '89 addressed some of these challenges.

Forestry Canada would like to thank the B.C. Ministry of Forests for co-sponsoring this event. In addition, a special thank-you is extended to the Steering Committee members, the many volunteers who provided countless hours and the City of Fort St. John for supporting this event. Many thanks to all the speakers, moderators, and displayers for providing excellent presentations and exhibits. Finally, the City of Fort St. John is to be commended for supplying that brand of northern hospitality found only in the Peace.

Walter Matosevic
Forestry Canada

OPENING REMARKS BY THE HONOURABLE FRANK OBERLE
MINISTER OF STATE (FORESTRY)

Mr. Chairman, Mr. Minister, distinguished International Guests, Friends:

When I first heard about this symposium, I thought how kind it was of you to honour me by selecting Fort St. John, in my riding and near my hometown, as the meeting place. Then I realized that the reason behind your choice of this hospitable community was a reflection of the new international interest in the fiber resources of this region, resources which one-dimensional thinking has taught us to consider as "weed speecies".

Once we removed our blinders and looked outside our own borders, we discovered that these so-called weeds have the characteristics, colour and taste which are ideally suited to the manufacturers of Asia's finest eating implements.

If, as they say, an army moves on its stomach, then Japan's technological strength is moved along by our chopsticks, and your symposium is being held in the chopstick capital of the world.

I am pleased that we will be hearing from so many international experts, especially on tomorrow's agenda. We have a great deal to learn from them, and I suggest that while we in Canada have accomplished much, we must set aside our pride and listen with a great deal of humility to our colleagues from other nations who speak from many years of experience.

This is not to say that Canadian forest professionals are in any way less qualified than their colleagues in other countries. In fact, the presence of so many learned scholars from all over the world reflects the fine reputation Canadian foresters have earned for themselves in foreign jurisdictions.

It is ironic that the best work Canadian foresters have done in applying their skills took place in other than our own country. There is a reason for this, of course, and it lies in the fact that so far, we did not require management of our forests to the same degree of intensity as was necessary in other parts of the world.

As we begin now to engage in the management practices our foresters have helped to establish elsewhere, we are at the beginning of a Canadian Renaissance in Forestry.

Public awareness of the importance of forests to our social and economic well-being is becoming a world-wide phenomenon. As we begin to embrace the principles of sustainable development in Canada, and as we balance the purely commercial aspects of our Canadian forest heritage with the social, environmental and ecological considerations, we find ourselves facing enormous new challenges and exciting new opportunities.

I can report to you that our Prime Minister and government have made a strong commitment to the concept of "sustainable development" as a guiding rule for all our policies and programs.

This concept is just an extension of the Golden Rule to our heirs: it is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Some might call it stewardship. We in the forest industry should be leaders in advancing this concept because it is a natural for us.

Of course, we in government also have to change the way Canada's forests are regarded if we are to offer the leadership and support which will be needed. I am pleased to say we are indeed reorganizing to meet this challenge.

To us in the federal government, the philosophical framework is clear. We will reflect the traditional commitment of Conservative governments to forestry, a commitment to fulfilling our custodial responsibility for the world's greatest storehouse of natural treasures.

Fortunately, we have the whole-hearted support of new public attitudes which are shaping government policy for a Canadian future in which forestry will play as prominent a part as it has done in Canada's past.

Let us be frank. Forestry itself must change, not so much in response to public attitudes but in response to the new realities which have brought those attitudes about.

We can no longer take our forests for granted. As well, we have to understand that forests can no longer be considered solely as industrial commodities.

The Association of B. C. Professional Foresters considers land-use conflicts the number one issue of the day.

Canadians expect our forests to be there when they want outdoor recreation. Forests are the backdrop for tourism, one of Canada's most important industries. We want our forests to provide homes for wildlife, and to stabilize and protect our ecological systems.

These competing forces pose a challenge to us in government whose responsibility it is to allocate the resources and to make the proper choices. I think I speak for my colleague, Mr. Parker as well, when I say that we are looking to you for the facts and the information that form the basis on which these choices can be made.

Clearly, our forest products sector must learn to adjust to new realities.

In some regions of our country, we already see dips in the supply curve of fiber, while at the same time there are sharp increases in the demand curve for our products world-wide.

We in the federal government intend to play a leadership role and contribute our share of the cost to strategic partnerships. Our common objective will be to substantially increase the yield of our commercial forests through research and more intensive management, and to assist the industry in its efforts to upgrade products and expand markets.

However, these are merely our own domestic problems to which I hope you will address your attention. Undoubtedly, you will also discuss the global environment in which our forests are a vital organ. There are alarm bells about the Greenhouse Effect, global warming which will change the ecology of every region on the planet. Trees which prosper here today may not survive changes in temperature or changes in rainfall. Who knows, we may be planting palms instead of pines.

We are all aware of the extra pressures our planet must endure as a result of the population explosion. It took from the beginning of time to the year 1950 A.D. for the human population to grow to 2.5-billion. In just 27 years, that number doubled, and between now and the year 2000, we will share the resources of our shrinking planet with an additional one hundred million new souls each year. That's the equivalent of creating a new Mexico or a new Bangladesh every year.

Yet the size of the planet does not increase. On the contrary, we must build into the equation the fact that each year the amount of arable land actually decreases by 8,700 square miles. Planetary forests have been reduced from 25% of the earth's surface to 20% in two decades. In our children's lifetimes, they could be gone altogether if these trends are allowed to continue. For every tree planted in a tropical region, ten are destroyed.

We must be sure that our management regimes do not succumb to these pressures, but in fact are designed to help relieve their effects.

In circumstances such as these of truly earth-shattering proportions, foresters have a special role to play. Rather than rejecting criticisms of current practices, or refusing to listen to legitimate concerns and suggestions about new courses of action, foresters must take the lead in closing the gap between concern and commitment.

After all, it is professionals like yourselves who have the knowledge and experience to help us chart our course for the century ahead. If we can repair our credibility, if we can be open and accessible, we will find people turning to us for solutions.

Right in this room we have all the knowledge necessary to turn this northern forest into a Boreal Eden:

* converting global excesses of CO_2 into cool oxygen;
* providing home for wildlife and birds;
* growing fiber and wood to sustain a productive industry employing a population much greater and at a higher standard than the present;
* and attracting tourists to enjoy the beauty of this very special place on this planet.

This symposium alone, of course, is not enough to address all these challenges. I appreciate more and more the skill of those circus jugglers who operate on a high wire. Given the abilities my job requires, I puzzle from time to time just why the Prime Minister appointed me to handle this portfolio. Nonetheless, I think I do understand the issues and I know the range of options which are open to us.

Fortunately for the country, most of the options are still open, but possibly not for much longer. We're going to have to make some choices. It is because I am aware of this, that I especially value the efforts behind this symposium, and I cherish very much the opportunity to be a part of it. I hope each of you, those who are so close to home, and those of you who have come so far to be with us, find this symposium stimulating, informative and satisfying.

In creating the world we dream of for the future, we are each a teacher, we are each a student. Together in this beautiful area, in friendship, and in a spirit of learning, your discussions have the potential to be of historic importance.

REMARKS BY THE HONOURABLE DAVE PARKER
MINISTER OF FORESTS

Good Morning.

Its a pleasure for me to attend the opening of this important symposium on mixedwood, which is of growing value and interest in British Columbia.

We are honoured to have with us for the next two days delegates from the Soviet Union, Sweden, Finland and the United States. They are here to share their knowledge and expertise on mixedwood.

On behalf of the premier, the government and the people of British Columbia, I want to extend to each one of them a warm welcome to our province. We hope your stay will be most enjoyable.

We are very grateful that you have come to British Columbia to share with us your knowledge and experience. We are sure we, in British Columbia, will benefit tremendously from your participation in this symposium.

British Columbia, as you are probably aware, is a relatively newcomer to the area of mixedwood.

In the past, we considered our deciduous species — mainly aspen, birch and cottonwood — to be weeds, or species having no commercial value. This was because our attention was concentrated on our coniferous species, which were always fetching high prices.

We first started using cottonwood that grows on our south coast — Vancouver Island and the Fraser Valley — when we found we could produce tissue paper from it. Today, balsam poplar is also harvested — 145,000 cubic metres a year — for the production of veneer in Fort Nelson.

The commercial use of aspen began in British Columbia only three years ago when a waferboard plant was opened in Dawson Creek and an annual cut of 450,000 cubic metres of aspen was allocated to the plant.

The development, over the past decade, of new technologies in the chemi-mechanical pulping process in Scandinavia has now prompted a surge of other developments in our province:

* a chemi-thermo-mechanical pulp mill near Chetwynd will require 452,000 cubic metres of aspen a year;

* a chemi-thermo-mechanical pulp mill at Taylor will require 500,000 cubic metres of aspen per year;

* a chipping plant in the Hudson's Hope/ Chetwynd area and a chemi-thermo-mechanical pulp mill at Britannia Beach on Howe Sound will require a total of 220 000 cubic metres of aspen per year;

* and possibly additional waferboard plants and pulp mills in the northeast.

Also, a timber-processing facility at Fort Nelson will soon be manufacturing disposal chopsticks for the Japanese market using 77 000 cubic metres of aspen a year.

You will note that these developments involve, for now, the harvesting of basically "pure" aspen stands that are concentrated in the province's northeast corner. While most of these "pure" stands are in the northeast, we do have significant mixedwood stands in this and other areas of the province.

West of the Rockies we will continue to emphasize the coniferous harvest, but here in the northeast, the greatest challenges lie in mixedwood management. However, we have yet to enter the era of harvesting and managing mixedwood stands in our province. This is the reason why we are here today — to prepare for the day when we have to deal with mixedwood stands more actively.

That day is not far off. We are, therefore, looking to you for information and guidance through this symposium. We want to learn from you. So, again, a warm welcome to British Columbia.

I am confident that this symposium will be very productive. I am looking forward to participating in some of the discussions and to talking with many of you during the breaks.

REMARKS BY HIS WORSHIP PATRICK WALSH

Mayor of Fort St. John

Ministers, honored guests, ladies and gentlemen:

My welcome will be brief but it will be heartfelt. It's a real pleasure on behalf of all of the citizens of Fort St. John and of the Council of Fort St. John to welcome you to this symposium which I feel will do so much for the future of the communities in northeastern Britisch Columbia and, of course, all of British Columbia and Canada. And to see all of you here for this Mixedwood '89 Symposium is very, very gratifying. Especially, our thanks to those of you who have come so far and bring such expertise to us. As the largest community in northeastern British Columbia, Fort St. John is particularly interested in the purpose of your symposium, to address the challenges of managing a mixedwood resource. We sit in the centre of that resource which is becoming one of the hottest areas in the forest industry. And we look forward to the knowledge that all of you will bring to this symposium to our benefit and that of our country.

As I understand it, the mixedwood resource is in its infancy in this area and the technology which is required to develop it is now being thought and developed here. In that regard I again want to express my sincerest thanks to all of you who have come to help us in this regard and in particular to Ken Pendergast and his very, very hard working committee for causing this symposium to happen and for ensuring that our resources will be be properly developed.

Welcome and have a good time. Come back again.

KEYNOTE ADDRESS

MIXEDWOOD FORESTS: SOME POLICY ISSUES OF THE '80s AND BEYOND

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ABSTRACT

The management of northern mixedwood forests hasbeen the focus of frequent meetings, especially in western Canada. Mixedwood forest is an important forest type in the boreal forest regions of Canada. The challenges of managing these forests are now real and pressing as the utilization of the northern hardwoods has grown in quantum leaps in the last 5 years. The extraction and utilization of hardwoods from the mixedwood forests of northern Canada requires close cooperation between government and industry and between companies with different species interests.

Thank you for the opportunity to participate in this symposium.

As keynote speaker, I realize my task is to challenge you as active participants in this symposium by focusing on the main issues of managing (in the broadest sense), harvesting and manufacturing of tree species which comprise "northern mixedwood." It is a formidable task but one I've enjoyed preparing for. In Canada, there have been a number of meetings dealing with mixedwood forests. I believe the frequency of those meetings will increase for reasons which will be clear as this symposium unfolds.

I'm sure many of you have attended some of the following conventions:

- Management and Utilization of Northern Mixed woods, Edmonton, April, 1988
- Aspen Pulp, Paper and Chemicals Workshop, Edmonton, March, 1987
- Aspen Wood Quality Workshop, Edmonton, 1987
- The Utilization of Hardwoods in Northern Alberta, Whitecourt, 1985
- Resources and Dynamics of the Boreal Zone, Thunder Bay, 1982
- Boreal Mixedwood Symposium, Thunder Bay, September, 1980
- Utilization of Western Canadian Hardwoods, Prince George, November, 1979
- Poplar Utilization Symposium, Edmonton, May, 1974

Alberta has also hosted a number of more focused workshops during the past 2 years - for example, on hardwood drying and grading.

This is by no means an exhaustive list, even for Canada. And the northern States, especially the Lake States, have a great interest in the subject of northern mixedwoods as well.

These conferences have been well attended, as indeed this one is, and this subject will continue to generate enormous interest from a wide variety of individuals. Of special significance is the interest in the various facets of northern mixedwood which has changed from the theoretical, academic and scientific to hard decisions now facing the forest manager and timber company foresters. Why? Primarily because in the past 4 to 5 years, there has been a virtual explosion in the use of northern hardwoods. And the dramatic increase in the use of northern hardwoods has changed or is changing our whole attitude to northern mixedwoods. Some of those issues I'll touch on in my remarks and those and many more will be elaborated on during this symposium.

How important are mixedwood forests to Canada? To discuss this issue, I believe it is important to link northern hardwoods and northern mixedwood. For a

number of reasons, as this paper illustrates, they are tightly interwoven and if added together are important components of the forest cover of Canada. In the Maritime provinces, they compromise between 54% (Nova Scotia and 62% (Prince Edward Island). Only in Newfoundland are they relatively unimportant as a percentage of the forest cover (6%). In Quebec (33%) and Ontario (49%), the figures are somewhat lower than the Maritimes. However, the national inventory statistics from which I derived those figures do not differentiate between the northern hardwoods and the southern hardwoods of Ontario.

For the three prairie provinces, the figures vary from a high of 56% in Alberta to a low of 31% for Manitoba. Saskatchewan's figure is 39%. As would be expected, British Columbia has a relatively low percentage of 15% but the diversity of the forests of B.C. from the coastal to the inland types makes this figure somewhat misleading. In this region, for example, I suspect it would be about 40% to 50% although the national statistics I used didn't have this information. The Northwest Territories led the list for Canada at 71%; Yukon was 27%. As a country, the mixedwood and hardwood cover types combined as a percentage of total unreserved productive forest land was 36% (22% was mixedwood, 14% was pure hardwood).

I think these figures establish mixedwood and hardwood stands as an important component of our Canadian forests.

To comment on the economic importance of our hardwood and mixedwood forest, it is useful perhaps to review activity in the past 10 years which has been predominately in western Canada.

To the few of you who may not have a feel for the incredible change in attitude towards our northern mixedwoods which has occurred, let me try and set the stage.

Ten years ago, Alberta had virtually no utilization of the 12 million m^3 of hardwood annual allowable cut (AAC). This is the single largest volume of northern hardwood in Canada. The situation was not very different in other Provinces, certainly not in western Canada.

Fred McDougall, former Deputy Minister of Forestry in Alberta, delivered a humorous after dinner speech to the 1979 Prince George conference. He joked about Alberta having sold all of its poplar in a deal with Texas. The Texans, he said, were going to transport poplar chips by water flume to Texas; throw away the chips and keep the water! Other speeches at the same conference were not much more optimistic of the use of aspen. Mr. E.T. Barnes of Prince George Pulp and Paper Ltd. stated "..for western Canada, the marketing of hardwood pulp represents an almost insurmountable challenge."

The experiences with other hardwoods were not any more encouraging, as related to the '79 conference.

- With respect to poplar plywood, Mr. J. Wells of Zeidler Forest Industries of Alberta said, "It is clear from our experience that the utilization of poplar for plywood is fraught with difficulties, which reflects in higher costs and less attractive prices in the market place."

- For solid wood products, Arden Rytz, Manager of the Alberta Forest Products Association, reviewed the failure of North American Stud Co. which tried to manufacture and market aspen stud lumber at its Slave Lake sawmill.

- Jack Toovey (of then British Columbia Forest Products, now Fletcher Challenge) said, "The crystal ball I am using does not show a major swing to hardwood utilization..."

In 1979, the only significant use of northern hardwoods was for waferboard with plants in New Brunswick, Quebec, Ontario, Saskatchewan and Alberta (not operating in 1979 but was bought by Weldwood and began operations in 1980).

All together, however, they were using less than 5% of the annual allowable cut for hardwoods for those provinces.

It is perhaps unfair of me to characterize our attitude in 1979 as one of general pessimism for the future of northern hardwoods. Many speakers at the 1979 Prince George Conference, including Fred McDougall, expressed belief that northern hardwoods' "day in the sun" would come. Tom Waterland, former Minister of Forests for British Columbia, boldly predicted "...these opportunities [for hardwoods] will be realized much sooner than most people think."

Don Fregren of the Alberta Forest Service said, "...It is expected that the growing impetus for fibre and energy will require that our deciduous resource be put to use within the next decade or two."

And today?

In Alberta alone, mills now operating, under construction or announced for construction, will use in excess of 7 million m^3 annually and have expansion commitments

of an additional 2 million m^3 annually. Alberta is currently negotiating with companies which will use, if they proceed, an additional 2 million m^3 annually which will bring us close to the allowable cut of 12 million m^3. While the utilization of hardwoods is not as dramatic in other western provinces, mills in British Columbia, Saskatchewan and Manitoba have new industrial capacity or committed capacity for an additional 3 million m^3 of hardwood annual allowable cut, according to my best estimate. Most of the expansion of industry development in hardwoods is for both chemical and mechanical pulp but there are increased uses for solid wood, oriented strand board and paper (newsprint, writing paper and tissues).

Our Cinderella has emerged from the ashes to show herself as a beautiful princess!

Having set the stage, let us describe the plot! Populus, the major species of our northern mixedwoods holds the key not only to its own commercial utilization but to some of our most valuable softwoods embedded in our northern mixedwoods. In Alberta, for example, a very high percentage of the more than 5 million m^3 of AAC of softwood which has been allocated to industry expansion in the last 3 years has been made possible by the dramatic increase in use of hardwoods. Without a use and market for hardwoods, the cost of accessing and extracting the softwood from the mixedwood stands was prohibitive.

Who are our actors for our hypothetical stage? In Alberta, we have Daishowa, Weldwood, Proctor & Gamble, Weyerhaeuser, Millar Western, Alberta Energy, Crestbrook (Alberta-Pacific), Alberta Newsprint, to name some of the leading roles. In British Columbia, Louisiana Pacific, Fibreco, Makin and Mitsubishi. In Saskatchewan, Weyerhaeuser, Nortek, Millar Western and MacMillan Bloedel. Manfor in Manitoba is and will continue to manufacture hardwoods.

But the forest manager, the researcher, the timber operator and government policy maker also have important roles in this developing scene.

I wish I could predict for you the climax of this developing drama but I'm afraid the play is not yet completely written. Perhaps the speakers at the conference can influence the outcome.

Let me turn for the remainder of my paper to the issues facing industry, government and research institutions on the subject of mixedwood forests.

I would like to raise a number of rhetorical questions of which some of you are already aware. Many of these themes will be discussed more fully by the outstanding speakers scheduled for the symposium. I realize in asking the questions that many of you will feel that sure, it's easy to ask the questions - what we need are answers! I confess I don't have the answers either but perhaps this symposium can lead us in the right direction to get the answers.

The first question: Are the competing interests in logging mixedwood stands prepared to resolve the serious planning and scheduling conflicts which are occurring? And what is the role of the government forester? Does he or she have to enter this conflict as a referee with a whistle or a soldier with heavy artillery? In most wars, everyone loses! I believe those of you caught in this conflict appreciate its importance. Clearly, this is one of the most challenging demands which requires compromise and appreciation for the other competing industrial interests. It is a microcosm of the conflicting land use debate between recreationists, industrial users and environmentalists. What kind of example can we establish for the non-fibre/fibre debate if we, in the forest community, cannot resolve our self-interest differences?

And while I am referring primarily to timber extraction conflicts in the above remarks, the same problem exists for sharing costs of inventory, regeneration and management planning. With respect to regeneration costs, is it reasonable for the softwood interests to bear the full cost of regenerating softwoods which is expensive and much more challenging than regenerating hardwoods in a mixedwood forest of competing industrial interests?

What will be the composition of our northern mixedwood sites 30 years after harvesting? Will the species composition meet the fibre requirement of the competing interests for these sites? For the government planning forester - are the long term management and silvicultural objectives clear for the timber user; clear, concise and, above all, fair? Have we as foresters fully overcome our natural bias against northern hardwoods as a commercial species? Perhaps a nasty question but understandable in light of our history and experience with hardwoods as I previously outlined.

Research! The research needs are an enormous challenge for northern mixedwood management. In Alberta, under the last Federal/Provincial Forestry Agreement, we spent perhaps half of our $23 million on forest product and forest management research relating to our hardwoods. And while I believe we have learned a lot with this expenditure, in many ways, we only now know to ask more intelligent questions, not provide all the answers. The dynamics of mixedwood forests, for example, are not clearly understood and we don't have a validated mixedwood growth and yield forecasting system in place!

What role should hardwood hybrids play in our future mixedwood and hardwood forests? I personally believe rotation age for our native hardwoods can be reduced well below 50 years. We know hybrids can be grown in less than half of that. But what are the implications of doing either? There is evidence to suggest nutrient depletion of hardwood sites can occur with short rotations.

And how do we manage a mixedwood site if we are growing hardwoods on a 50 year rotation, for example, and spruce on a 75 year rotation? We have similar problems on mixedwood now where we have an overstory of mature hardwoods and an understory of young spruce.

What about the quality of the fibre from a short rotation? You can sure catch the attention of forest investors with short rotations - for example, the current Japanese-Thai negotiations for eucalyptus plantations in Thailand and the wave of interest in plantation hardwoods (largely eucalyptus) in tropical and sub-tropical climates.

A host of regeneration questions remain unanswered. What are the long term implications of coppice regeneration of hardwoods? What is the most cost efficient way to reduce the number of regenerating stems on a hardwood or mixedwood site?

In the area of forest protection, many of the mixed and pure hardwood stands in northern Alberta are a reflection of our failed protection efforts in the past. Today, as a result of experience, technology and funding, we can perhaps avoid those massive failures. This was enormous implications for species composition of northern forests. How will our hardwood forest regenerating from logging compare in quality with fire regenerated forest?

And the dramatic increase in use of northern hardwoods is already changing our attitude towards herbicides. I'm certainly not suggesting herbicide use is no longer justified but we can no longer use the analogy of aspen as weed in our garden of expensive softwood crops!

Ladies and gentlemen, I haven't even touched on the emerging social and environmental pressure from the public resisting any logging of our northern mixedwood. But my time allocation is just about up and it just wouldn't be correct for the keynote speaker to set a bad example now - would it?

Thank you.

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WORLD DEMAND FOR FOREST PRODUCTS AND INDUSTRIAL ROUNDWOOD

W.J.B. PALMER
Woodbridge, Reed and Associates, Vancouver, B.C.

WORLD DEMAND IN PERSPECTIVE

In 1985, world production of industrial roundwood was 1.5 billion m^3, a gain over 1970 of 233 million m^3. To put this increment in perspective it was 1.3 times the average Canadian timber harvest (Figure 1).

North America dominates world commercial timber production. This is true in terms of both the absolute level of production and the historic 15 year increment. To 1985, Canada led the way in new softwood supply, China, the United States and Brazil followed in that order. In most other regions, softwood production registered only modest gains (e.g. Western Europe and Australia/New Zealand) or, it declined (e.g. Nordic Countries, the USSR and Japan) (Figure 2).

The increment from the developing nations of South East Asia, namely Indonesia, Malaysia, and to a lesser extent, India, accounted for nearly 32% of the world's new supply of hardwoods. Due to an early and rapid exploitation of the natural tropical hardwood forests in Malaysia and Indonesia most of those gains had been registered by the mid 1970s and since that time the increment has been relatively modest. The opposite has been true in Brazil where accelerating harvests increasingly from plantation, gave that country over 20% of the increment and doubled its share of the world harvest from 3.5% to 7%.

Although the United States is a major hardwood producer, the same has not been true of Canada. We account for only 2% of the world's production and the 1970-85 increment was negligible. As we shall soon see, this situation should change dramatically.

PAPER AND PAPERBOARD

Since the 1970's, increasing world demand for cultural papers and packaging materials has resulted in pulp and paper industry growth rates that have outpaced those for wood products (Table 1). Although this trend is projected to continue into the future, some significant gains are expected for lumber and panelboards (Table 2). In fact, for softwood lumber products, much of the anticipated gain had already been realized by 1987-88.

In paper and paperboard, North America and Western Europe will continue to be the major producing regions with Canada and the Nordic countries (Norscan) retaining their positions as the world's principal exporters. Latin America, the Asia-Pacific and the centrally planned economies are forecasted to show significant production gains but as can be seen from Table 3, these increases are not expected to keep pace with domestic demand.

Some other noteworthy points are as follows:

- The USA, the world's largest paper producer will become somewhat more self-sufficient through a combination of increased utilization of domestic fibre sources (both virgin fibre and waste papers) and paper grade pulp imports from Canada and Latin America.

- Due to their relatively high fibre costs, the Scandinavian countries are expected to continue to integrate more pulp capacity into paper production so that the wood component represents a smaller portion of the end product cost. Most of this increased production is expected to be marketed in Western Europe.

- Canada will continue to specialize in mechanical pulp based paper grades but there will be a progressive shift towards higher valued semi-commodities containing both softwood and hardwood chemical pulps.

WOOD PULP

The increased production of paper and paperboard will result in an increased demand for wood pulp and other fibre sources including recycled waste paper and smaller volumes of agricultural residues (bagasse) and non-wood fibres (reeds, bamboo, etc.).

Technological changes will affect the volumes and grades of wood pulp to be consumed in the paper furnish. These anticipated changes are summarized as follows:

1) increased usage of higher yield (mechanical) pulps;
2) increased usage of hardwood kraft pulps;

FIGURE 1
WORLD PRODUCTION OF INDUSTRIAL ROUNDWOOD, 1985

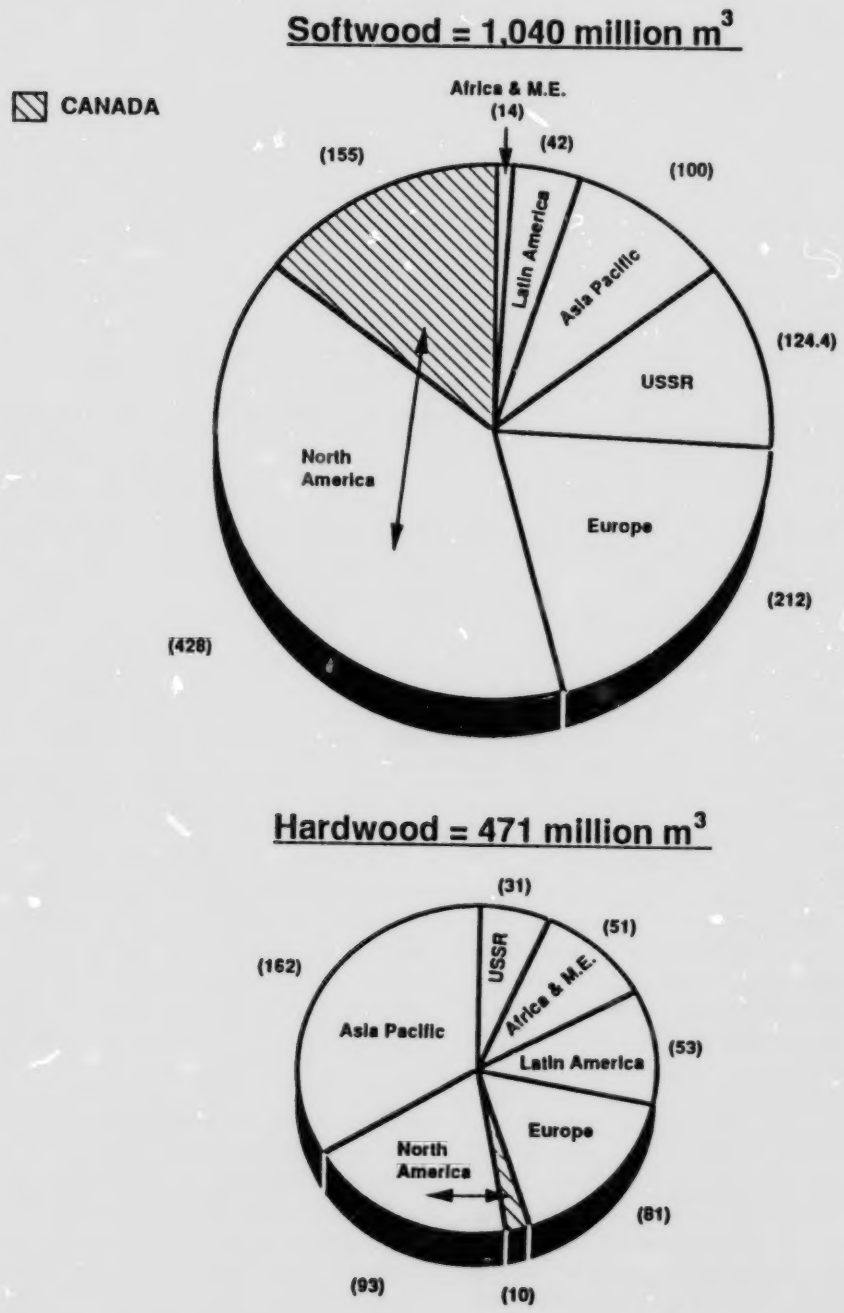


Table 1
World Consumption of Forest Products

Products	Units	1970 Volume	1985 Volume	Volume Increment	Growth Rate %
Paper & Paperboard	million tonnes	128	193	65	2.8
Wood Pulp	million tonnes	95	129	34	2.0
Lumber Products	million m^3	407	462	55	0.5
Panelboards	million m^3	70	109	39	2.0

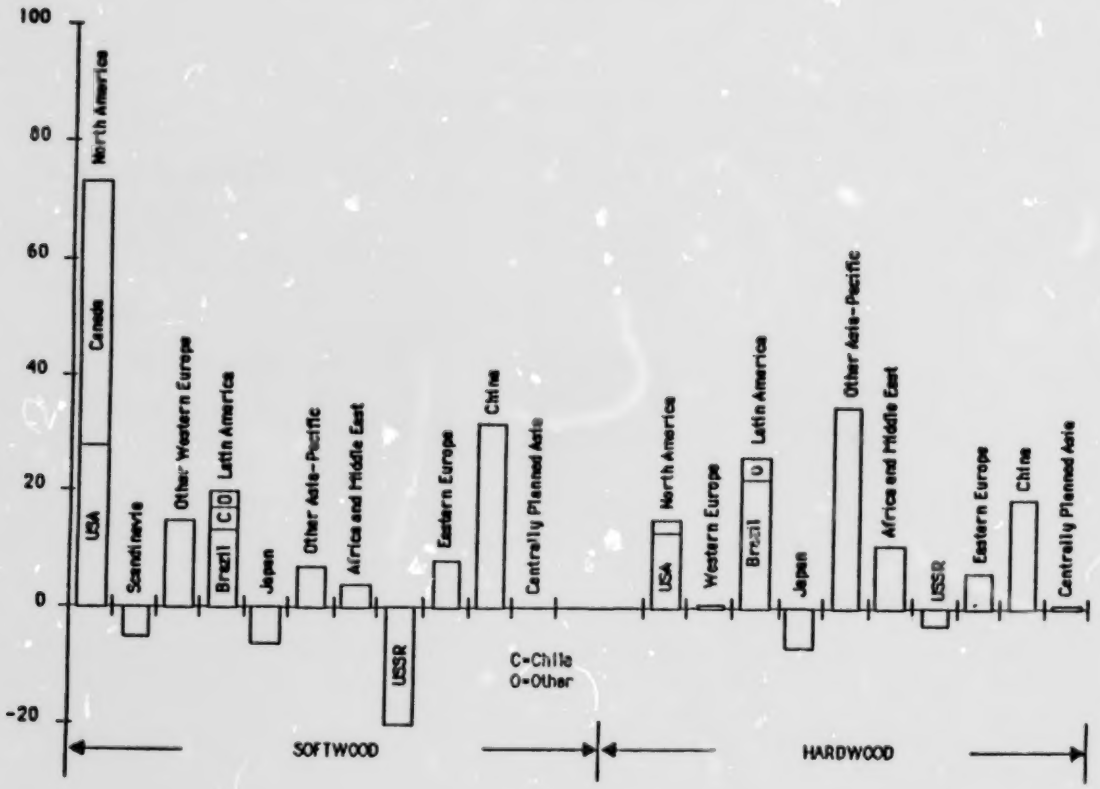
Table 2
World Outlook for Forest Products Consumption

Products	Units	1985 Volume	2000 Volume	Volume Increment	Growth Rate %
Paper & Paperboard	million tonnes	193	270	77	2.3
Wood Pulp	million tonnes	130	180	51	2.2
Lumber Products	million m^3	462	570	108	1.4
Panelboards	million m^3	109	154	45	2.4

Table 3
Current and Projected Regional
Self-Sufficiency for Paper & Paperboard
(million tonnes)

	Surplus or (Deficit) 1985	Surplus or (Deficit) 2000	Projected Change 1985-2000
North America	2.3	7.5	+5.2
Canada	9.3	12.8	+3.5
USA	(7.0)	(5.3)	+1.7
Western Europe	3.8	8.3	+4.5
Nordic	12.4	18.1	+5.7
Others	(8.6)	(9.8)	-1.2
Latin America	(1.0)	(3.7)	-2.7
Brazil	0.4	0.7	+0.3
Chile	0.1	0.2	+0.1
Others	(1.5)	(4.6)	-2.1
Asia-Pacific	(2.6)	(3.5)	-0.9
Japan	0.2	(2.0)	-2.2
Others	(2.8)	(1.5)	+1.3
Centrally Planned	(0.4)	(6.3)	-5.9
USSR	0.4	0.6	+0.2
E. Europe	(0.4)	(1.0)	-0.6
China/Other Asia	(0.4)	(5.9)	-5.5
Africa & Middle East	(1.9)	(2.1)	-0.4

Figure 2
Industrial Roundwood
1975–85 Increment



3) increased usage of recycled waste papers;
4) increased usage of filling and coating agents.

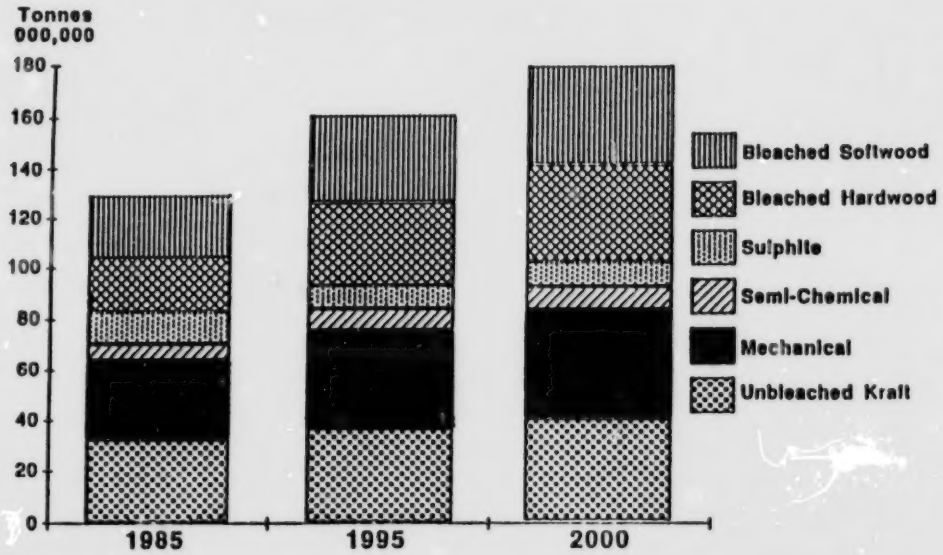
Figure 3 illustrates the expected consumption of paper grade wood pulp to the year 2000 by individual grade. As this figure shows, kraft pulps will continue to be the major constituents in paper production. Consumption of bleached hardwood kraft is projected to continue to grow at a faster pace than other grades of wood pulp and is expected to surpass the usage of softwood kraft by the year 2000.

The Latin American countries are forecasted to supply an increasing volume of new hardwood timber resources from eucalyptus plantations. The relatively fast growth period for this species provides a decided advantage over competing species. In addition to the advantage of faster growth periods, eucalyptus has also become a desirable species for papermaking due to its technical qualities. Canadian aspen and white birch BKPs compare very favourably with eucalypt BKP in many papermaking applications.

The usage of higher yield mechanical pulps is also expected to increase. These pulps include thermomechanical (TMP) and chemi-thermomechanical (CTMP) pulps which have been developed over the last 10 years. Initially, only softwood fibres were used (TMP) but the commercialization of the CTMP process and the growing desirability of using hardwood fibres has led to the production of mixed wood (e.g. spruce/aspen) CTMPs. Canada with its low power costs and spruce/aspen fibre resources is now the growth centre for high quality bleached CTMP. While the technology is suitable for other regions including Latin America and Asia, it requires extremely high power consumption which will restrict its usage in high power cost regions.

Within the context of an approximate 50 million tonne increase in world pulp consumption the estimated changes in regional self-sufficiency are shown in Table 4. The current surplus position of North America's wood pulp producers should increase further as more usage is made of available hardwoods through expansions of existing

Figure 3
World Paper Grade Wood Pulp Consumption
1985-2000



Source: FAO, WRA

mills and the establishment of new greenfield capacity for chemi-mechanical and chemical pulps.

Western Europe's deficit position is expected to grow as a result of a movement to increase paper production in the Scandinavian countries. Utilizing more domestic pulp production will leave less available for other Western European paper producers.

In the Asia-Pacific, the regional pulp deficit is projected to increase due to a relatively greater expansion of paper and paperboard production.

LUMBER PRODUCTS

World consumption of lumber products is expected to increase at an average rate of 1.4% per annum over the remainder of this century as compared to only 0.5% per annum during the 1970 to 1985 period. This apparently dramatic increase in consumption is partially explained by the fact that in the 1985 base year, lumber consumption was still suffering the effects of the 1981 to 1983 recession and had not yet recovered to the previous peaks recorded during the 1979 to 1980 period. Very significant recovery did occur in 1986-88. When world consumption is viewed over the entire 1970 to 2000 period, the apparent growth rate becomes 1.15% per year (Figure 4).

World use of hardwood lumber products is projected to expand at 2.0% per year, a rate which is considerably in excess of the average annual 1.3% projected for softwood. The majority of the world's hardwood resources are found in the developing world and this is where the pace of economic expansion is expected to be greatest. An exception is Western Europe (including Scandinavia) where strong growth in hardwood demand is forecast. In terms of volume, however, incremental demand for softwood lumber products at 70 million m^3 is projected to be 1.8 times greater than that for hardwood (34.0 million m^3). Over 80% of this incremental softwood demand is expected to come from the industrialized nations plus China and the USSR. That is, from the regions that contain the vast majority of the world's softwood resources.

Canada is expected to remain the world's principal exporter of softwood lumber and the increase in export availability is apparently offset by additional US demand. However, increased US production in the medium term and in the longer terms, export supply from other surplus regions such as Chile will allow incremental Canadian exports to other deficit markets.

The areas which demonstrate the greatest increase in deficit are Western Europe, China and Japan (Table 5). There is not expected to be any increase in lumber production in Scandinavia and, though substantial production

Table 4
Current and Projected Regional Self-Sufficiency for Paper Grade Wood Pulp
(million tonnes)

	Apparent Surplus or (Deficit) 1985	2000	Projected Change 1985-2000
North America	5.7	10.6	+4.9
Western Europe	(3.0)	(6.7)	-3.7
Latin America	1.2	3.8	+2.6
Asia Pacific	(2.9)	(7.7)	-4.8
Africa & Middle East	0.5	-	-0.5
Centrally Planned	0.1	-	-0.1

Source: WRA

Figure 4
Historical and Projected Total Lumber Consumption

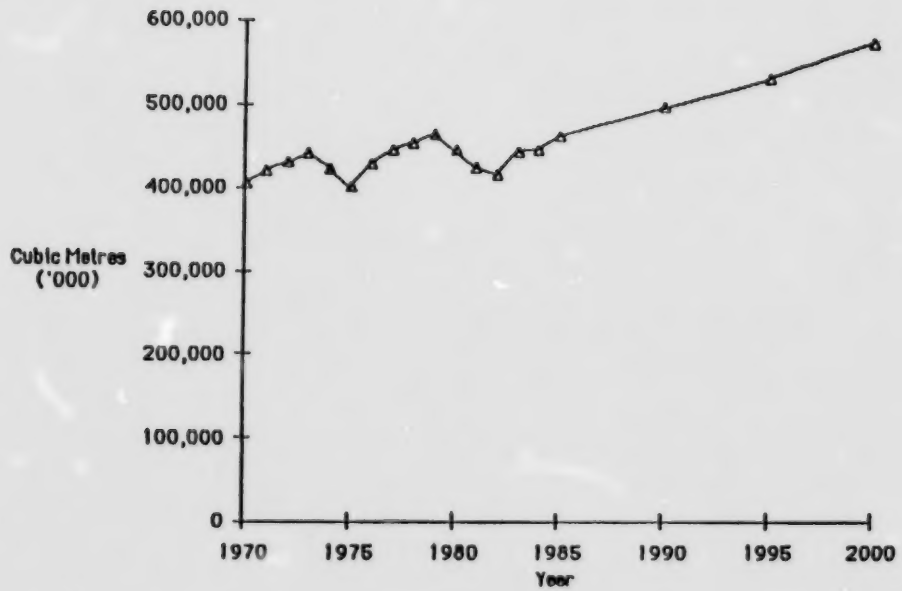


Table 5
Self-Sufficiency Projections for Lumber Products
(million cubic metres)

	Apparent Surplus or (Deficit) 1985		2000		Projected Change 1985-2000	
	Swd	Hwd	Swd	Hwd	Swd	Hwd
North America	**7.8**	**(0.2)**	**8**	**3**	**-**	**+3**
Canada	38.0	(0.3)	40	-	+2	-
United States	(30.2)	0.1	(32)	3	-2	+3
Western Europe	**(2.0)**	**(3.2)**	**(10)**	**(10)**	**-8**	**-7**
Scandinavia	12.4	(0.2)	11	-	-1	-
Others	(14.4)	(3.0)	(21)	(10)	-7	-7
Latin America	**(0.8)**	**0.2**	**2**	**5**	**+3**	**+5**
Brazil	0.1	0.1	(1)	3	-1	+3
Chile	0.7	-	4	-	+3	-
Others	(1.6)	0.1	(1)	2	+1	+2
Asia-Pacific	**(4.7)**	**3.5**	**(4)**	**3**	**+1**	**-1**
Japan	(4.1)	(1.1)	(7)	(3)	-3	-2
Dev. Oceania	(0.6)	(0.3)	2	(1)	+3	-1
Others	-	4.9	1	7	+1	+2
Africa & Middle East	**(6.2)**	**(0.5)**	**(5)**	**(1)**	**+1**	**-**
Centrally Planned	**6.6**	**(0.4)**	**9**	**-**	**+2**	**-**
USSR/E. Europe	6.5	0.1	13	1	+6	+1
China/Other Asia	0.1	(0.5)	(4)	(1)	-4	-1

Source: FAO, WRA

increases are looked for in other Western European countries, there will be a growing need for imports. The likely suppliers will be Developed Oceania, Chile and USSR/ Eastern Europe. In addition it is clear that China could emerge as an important market for exported lumber.

The Asian nations (other than Japan) will continue to be the leading exporters of hardwood lumber products but, by 2000, Latin America and the United States will have become important factors in the hardwood export trade. On the import side, the most significant change is the large increase in the deficits projected for Western Europe where net import requirements are projected to increase from 3.0 million m^3 in 1985 to 10 million m^3 by the year 2000. In addition Japanese import requirements for hardwood lumber also will increase. It is projected that there will be substantially more processing of logs in the country of origin rather than log export.

PANELBOARDS

Worldwide consumption of wood based panelboards is expected to continue to exhibit healthy growth but at a somewhat slower pace than was experienced during the past 15 years (Figure 5). The greatest volume gains are forecasted to occur in Western Europe, the Asia-Pacific, Latin America and the Soviet Block countries. Relatively slow, stable growth is projected for North America. The dominance of the North American industry will decline so that, whereas in 1985 it represented about one-third of production, by the year 2000 this share will have dropped to one-quarter.

Plywood is expected to lose some market share as the principal growth products will be reconstituted boards. In North America these boards are likely to be mainly struc-

Figure 5
Historical & Projected Worldwide Wood-Based Panel Consumption
(thousand m^3)

tural, that is OSB/waferboard, whereas in regions such as Japan/Korea/Taiwan, non-structural boards such as MDF/particleboard will predominate. In Malaysia and Indonesia, plywood will continue to be the dominant product.

Table 6 provides regional self-sufficiency data for wood based panels in 1985 and a projection to the year 2000. The salient points are that the South East Asian nations maintain their role as the world's principal source of panel products for export and that the non-Scandinavian countries of Western Europe plus Japan continue to be the major importers.

INDUSTRIAL ROUNDWOOD

During the late 1970s as resource exploitation accelerated on the strength of soaring commodity values, it was widely proclaimed that serious timber shortage were imminent. The deep and protracted recession of the early 1980s saw a reversal of this thinking as commodity prices fell and logging equipment stood idle. Today, the prevailing view is that on a global basis, there is no shortage of fibre. Our analysis indicates that during the short term (i.e. up to 1995) this is indeed the case. Beyond that, consumption projections based on constant real prices for paper, paperboards and commodity wood products suggest that incremental fibre demand to the year 2000 might well be in excess of the apparent incremental supply. WRA's estimate of incremental roundwood demand to the year 2000 is 480 million m^3 as compared to a projected new supply of 380 million. As can be seen from Table 7 this projected shortfall is about 20% softwood and 80% hardwood timber.

These indicated supply shortfalls are significant (i.e. 10% and 49% of the projected softwood and hardwood supply increments respectively) but the total deficit is not particularly substantial (5% of total projected supply). The potential existence of a supply shortfall suggests that there could be some real price increases for forest products rather than the constant prices assumed. This in turn would have an impact on both the volume of final products demanded and the amount of fibre supplied. That is:

1) rising real prices would constrain demand for fibre intensive products and encourage substitution of fibre efficient technologies;

Table 6
Apparent Self-Sufficiency in Panelboards
(million cubic metres)

	Surplus or (Deficit) 1985	Surplus or (Deficit) 2000	Projected Change 1985-2000
North America	(1.2)	1.0	+2.2
Canada	1.5	2.0	+0.5
USA	(2.7)	(1.0)	+1.7
Western Europe	(2.8)	(5.0)	-2.2
Latin America	0.3	n.s.	-0.3
Asia-Pacific	4.6	5.0	+0.4
Japan	(0.5)	(4.0)	-3.5
Others	5.1	9.0	+3.9
Centrally Planned	0.7	n.s.	-0.7
USSR/E. Europe	0.7	-	-0.7
China/Other Asia	n.s.	n.s.	n.s.
Africa & Middle East	(1.4)	(1.0)	+0.4

n.s. not significant

Table 7
Canadian Timber
Domestic Demand and Supply
(million cubic metres)

	Current Demand	Pot. Demand in 2010	Apparent Increment Demand	Apparent Increment Supply	Surplus or (Deficit)
Softwood	162	192	30	18	(12)
Hardwood	24	52	28	34	6
Total	**186**	**244**	**58**	**52**	**(6)**

2) real price increases would extend the economic margin and bring into use fibre resources which are now considered to be uneconomic;

3) the relatively large shortfall in hardwood supply should encourage the establishment of more plantations of fast growing hardwoods for the pulp/paper and reconstituted panelboard industries.

IMPLICATION FOR CANADA AND THE BOREAL FORESTS

By the year 2000, market drive opportunities for Canada's traditional forest products exports, construction grade softwood lumber, softwood bleached kraft pulp and newsprint will, due to softwood fibre availability constraints likely exceed our capacity to supply. It has been projected that in 2010 this softwood deficit will be in the order of 12 million cubic metres per year (Table 7). Despite this, underutilized hardwood resources, increasing market acceptance of high quality bleached CTMP, forward integration into paper products and higher valued added processing options offer tremendous scope for forest industry expansion. The substantial capital investments required to meet the market challenge are estimated to average $5 billion per year in 1989 dollars. This capital requirement may well prove to be a more significant constraint on growth than fibre supply.

With respect to the Boreal mixedwood forests, the principal species, white spruce and trembling aspen have fibre characteristics and wood brightness that render them as extremely suitable for pulps and subsequent high quality papers. As mentioned earlier, aspen has the potential to be a strong competitor to plantation grown eucalypt. Spruce, balsam and lodgepole/jack pine (in descending order of fibre quality) are superior to the pines of the southern USA. Thus, it is not surprising that in the Boreal region Western Canada alone has two new greenfield pulp mills and one expansion into paper have just come into production, two new pulp and one new paper mill are under construction while seven more pulp and paper projects are under active study. The total investment involved is in excess of $4.5 billion.

PLANNING FOR THE NORTHERN MIXEDWOOD FOREST

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INTRODUCTION

Interest in Canada's mixedwood forests has increased dramatically during the current decade. This has been prompted by new circumstances in three fields: timber supply, markets and technology. Some would add a fourth item to this list, namely the widespread concern with conservation issues. This concern is expressed in a preoccupation with forest land management.

The task assigned for this paper is to provide a context for the conference discussions. My objective is to paint the big picture as a strategic planner might see it. Others will deal with the detailed technical and biological aspects of mixedwood management and utilization.

With this in mind, the first section provides some historical timber supply and demand relationships. The second deals with the theory and process of planning while the third moves down to a more practical level. Then it will be appropriate to draw some policy implications for senior governments and for industry.

The question put to me initially was this: Have we got it right at the planning stage? I do not believe that we have, and the reason is that the challenges of timber supply imbalances, research, land use allocation and so on have not yet been seen in proper perspective. There is no sense of vision, of strategic goals and priorities, and of accountability for stewardship. The result is defective planning which is pervasive among those we elect, a defect observed throughout the public sector, within industry and in the scores of preservationist groups.

TIMBER SUPPLY CONTEXT

Canada was and is a forest nation. Some 70 percent of the land within the 10 provinces is still classed as forest land. Our earliest history is a record of exploitation of this resource, first for beaver and other skins, then for masts required by sailing vessels. And while timber was used by settlers as an abundant building material, they also looked on the forest as an impediment to agriculture and burned large tracts to make way for farms.

Early in this century, Canada became a leading exporter of lumber, then added newsprint and chemical pulp to the list. Today, Canada supplies a stable 23-25 percent of world trade in manufactured forest products. The single most important manufacturing sector continues to be based on the forest, which contributes directly and indirectly to a million jobs. Moreover, we believe the outlook for our forest sector is very positive for the medium and long term as tropical and temperate forests are generally being depleted more rapidly than they are being replaced.

However, Canada's forests are not inexhaustible, as far as industrial timber is concerned. In fact, the production of coniferous roundwood has now reached the sustainable harvest level ceiling and in some cases surpassed it, given today's level of forest management. There is a lengthening list of sawmills and plywood plants which have shut down permanently or are operating on a curtailed basis. The 10 provinces currently calculate the sustainable annual allowable cut of softwoods at 166 million m^3. In 1987 we cut approximately 175 million m^3.

On balance, Canada will never run out of trees. The more relevant question is this: Do we have an assured supply of industrial wood that can be delivered to processing mills at a competitive cost? The answer is that prime softwood sawlog supplies are tightening every year, as we see in Quebec, Ontario, B.C. and other regions.

The preservation movement says we are running out of wilderness. They are laying claim to large areas of licensed old growth timber that is scheduled for harvesting in the next 20 years. The public needs to be made aware that approximately half of the forest land in Canada is not available and suitable for industrial use. It is in a category often referred to as "de facto" wilderness. In addition, substantial areas of provincial land have already been set aside for wilderness, recreation and other purposes. In

B.C. about 6.5 percent has been reserved, an area the size of Nova Scotia, and much of it is forested. British Columbia has the finest system of parks, recreation and wilderness in Canada, if not in the world. In my view, the combination of superb quality, diversity and accessibility is unequalled anywhere on the globe.

In contrast to softwood supply problems, hardwood timber is relatively plentiful. In Canada there is ample room to double or triple the output of hardwood logs. But these cannot compensate for the shortages of softwoods which threaten scores of communities. Industry's response will take several forms, such as closer utilization and more intensive silviculture.

There is good reason to believe that Canada's forest land base could support harvest levels which are much higher than we now calculate. Our present harvest is about 190 million m^3 annually. A minimum goal for roundwood production should be to at least double output by 2040. Resource stewardship is the key to ensuring a promising future for succeeding generations. This not only means investing for industrial use, but also in expanded opportunities for recreation and other forest uses. My vision of Canadian forest resource management seeks a *better* life, not simply a *richer* life.

PLANNING CONCEPTS

I have found it useful to approach the exercise of planning as a process in the following sequence: societal values, vision, strategic thinking, policy formulation, operational planning, implementation and monitoring. This originates in a personal philosophy which identifies key values that are adopted as guidelines for social behaviour. Some of the main values of significance for land use planning are stewardship, equity, community stability, quality of life and accountability. Thus, we come to accept a custodial responsibility on behalf of the current generation and those to follow. Wise use and conservation is extended to embrace preservation. Having affirmed the kinds of values listed, ideally society will resolve conflict by consensus and trade-off.

Vision can be taken as the next stage in the sequence. I once heard a preacher say that a vision was "picturing in your mind's eye what God wants to happen". Now you don't have to be a mystic to be a visionary, but the figure is apt, nonetheless. As in the case of most values, the reference point for a vision is largely outside the individual and his own short term self interest.

Strategic thinking involves a number of elements, all of them concerned with the options open to us in the long term. The politician examines these alternative options and chooses one of them. That process, which may be spread over an extended period, is what is called policy formulation. Policy can be defined concisely in a very few words:It is a declaration of intent. "This is what we intend to do". The policy is then transmitted to bureaucrats for operational, short term planning and implementation.

The foregoing is of course simplistic. As R.G. Florence (1979) has pointed out from Australia, the pathway of planning in forestry is not a linear one. Rather it reflects the continuing evolution of social attitudes toward the use of land, and specifically in the direction of environmental conservation. He stresses the significance of a corresponding attitudinal change on the part of governments and industry. Someone has said that a strategy is a plan in a tuxedo, but Florence reminds us that a strategy is much more than that. It can be regarded simultaneously as a way of thinking about the future, an approach to decision making, and a method of coping with uncertainty and risk.

Peter Drucker (1976) is another writer who has contributed to our understanding of this topic. He declares first that strategic planning is the entrepreneurial skill. It is definitely not a box of tricks or techniques, such as complicated economic modelling. Second, it is not a method of quantification, but an exercise in which "larger or smaller", and "sooner or later" may be adequate as initial parameters. Third, it is not forecasting, or as he puts it:

> "We must start out with the premise that forecasting is not a respectable human activity and not worthwhile beyond the shortest periods. Strategic planning is necessary precisely because we cannot forecast."

This is due, he says, because the entrepreneur's job is to influence events and foster innovation in such a way that the economic, political and social situation is changed. To put this another way, he upsets the probabilities on which forecasts are based.

Drucker says, fourthly, that strategic planning is not an attempt to eliminate risk, but rather to deal consciously with it. He argues that the process is a continuous one in which the leader makes risk-taking decisions, organizes efforts to carry out those decisions, and measures results against expectations. Finally, he would not substitute knowledge for judgement.

To sum up Drucker, he believes that strategic planning does not deal with future decisions, after all the facts are in, but with the "futurity of present decisions". The aim is action, now.

A third relevant author is Alf Leslie (1986), who has some useful advice based on his New Zealand and FAO experience. He first distinguishes between prescriptive and indicative planning. The prescriptive kind is only appropriate in the short term and at the local or site specific level where governments have no primary function. In contrast, indicative planning provides a broad framework, suggesting a range of targets which bracket what a government thinks should happen.

Then Leslie takes a rather surprising position on the questions of data needs and predictability. He maintains that future resource availability is much more predictable than markets. After all, there is a wide choice of excellent timber simulation models, and we need only to understand owner objectives and silviculture technology in order to identify resource options for the next 30-50 years. Leslie says that markets are less knowable and that these can be influenced by the emergence of new products and new customers as competitors fight for market shares.

I agree that the market place is highly uncertain, even a decade away. Moreover, as Canadian forest companies know so well, sharp adjustments in exchange rates can throw market projections "down the burner" in short order.

The fourth author is a forester from the state of Maine with an astute insight into strategic planning. Lloyd Irland (1986) emphasizes three main types of uncertainty: growth and yield, consumption trends, and technological change. Then he makes five solid points which strategic thinkers would do well to remember. First, in dealing with uncertainty, one has to begin with a set of specific, plausible assumptions. You can't wait for perfect data. Second, goals themselves are variable. Planning is not a straight line from data to targets. Optimizing models like FORPLAN do not adequately recognize the dynamism which prevails. Irland believes that, more than anything else, strategic planning opens up the debate about goals and assumptions.

His third point is that a time horizon of 5-10 years is not of strategic dimensions. Moreover, the elevation of operational guidelines to the strategic level will produce nonsense results. For example, a corporate hurdle rate for new investment of say 14 percent is totally wrong for resource planning. Such a rate would simply prompt you to liquidate old growth timber and buy junk bonds. There is a subtle message here for all of us. You will never make a visionary, or a strategic planner, out of a forester who has fallen in love with his interest tables.

Irland's fourth point is that a strategy must take into account social purpose and political imperatives. To illustrate, more forest land will indeed be set aside for wilderness preservation and recreation. To assume otherwise is simply an idle diversion.

Point five ought to be a forceful one in today's contentious debates over land use. Irland suggests strategic planning is a powerful way to educate the public. He states that forestry programs will succeed only when presented "...in the context of a compelling strategic vision that shows how all will benefit from improved forestry."

Of the four writers cited above, I believe that Irland does more for a practical understanding of the basics of strategic planning than any of the others. He de-mystifies the process by removing it from the magical incantations of formulae economists and their fellow travellers, the computer specialists.

Before commenting on the implications for policy, it may be helpful to recapitulate, as I see them, the essential phases which a strategic plan must incorporate. Given the core values of a community or a company, the consecutive steps are as follows:

1. Policies
   - which are integrated and predictable
2. Targets
   - these must be do-able and measurable
3. Priorities
   - thoughtfully ranked
4. Action plan
   - over specified periods of time
5. Accountability
   - to named individuals or positions
6. Monitoring
   - regular feedback and modification

Do we have this kind of strategic thinking in place now in respect to the forest sector, either in Ottawa or in Victoria? The answer is: Not yet. The absence of consistency in policies, targets and priorities is patently obvious.

FEDERAL IMPLICATIONS

Forest policies at the federal level are now being reassessed, not an easy task with the 20 or so departments and agencies impinging one way or another on the resource base itself and on forest industry operations. Back in 1979, John Fraser who was then Environment Minister and in charge of the Canadian Forestry Service, invented the Federal Forest Sector Strategy Committee. In the early 1980's I found it to be an invaluable mechanism to sell the urgency of forestry in Ottawa. Its use was discontinued

five years ago and forestry's place in the Ottawa agenda has suffered in predictible fashion.

Just before the federal election in 1984, full departmental status was announced for forestry. Subsequently the official title was changed to Forestry Canada, and in June 1989 Bill C-29 was tabled in the House of Commons. Debate on second reading is at the front of the queue for the upcoming session. This may prove troublesome, inasmuch as the 1981 Forest Sector Strategy for Canada is obsolete and has not been replaced with a new strategic view. In addition, the new legislation will confine Forestry Canada principally to forestry science and does not even mention the joint federal-provincial forest renewal agreements known as FRDA's.

Many in the forestry constituency had counted on a Department of Forestry and Forest Industries, as recommended repeatedly in the last 10 years, and most recently in the Canadian Council of Forest Ministers 1987 forestry conference in St. John. We are left instead with the Siamese twins of Forestry Canada and Industry, Science and Technology. The respective ministers co-sponsor, but do not co-chair, a federal Forest Sector Advisory Council. The relative weight of budgets, person years and programs makes Forestry Canada the junior partner.

Meanwhile Forestry Canada, like other federal line departments, dances to the tune of Environment Canada, which meddles in erratic and troublesome fashion in forestry affairs. This is like sharing your kitchen with a gorilla. Environment Canada concedes that it has no strategy, and in my personal opinion its interventions in forestry have been blundering at best.

The most serious handicap at the present time is absence of a strategic plan for forestry. One was approved by the federal Cabinet in 1981 and was reinforced by related policies on forest renewal, research and education. In 1981 the target was set for Canada's coniferous roundwood output at 210 million m^3 for the year 2010. Targets for silviculture spending were projected to double. These were neither confirmed nor revised in the 1987 conference recommendations in St. John, nor have we any new targets in the two years since that event.

Those earlier policies and objectives are now obsolete. A new and visionary federal strategy for forestry is long overdue, beginning with a fresh statement of values covering stewardship, conservation and preservation of timber and non-timber values alike. The Hon. Frank Oberle deserves the most vigorous support of the forest constituency right now as he fights to restore the forestry mandate in Ottawa.

PROVINCIAL IMPLICATIONS

The need for a provincial forestry strategy is equally clear and pressing in British Columbia. We can of course infer from actions of the provincial government, and from its various ad hoc pronouncements, that a strategy does indeed exist. In the early 1980's the Ministry of Forests was savaged by roughly a one third cut in person years and budget. The Strategic Studies Branch disappeared.

Even earlier, in 1978 the Forest and Range Resource Analysis published by the Ministry included a projected falldown in timber availability over the next century. In 1985, the second such analysis published by the Ministry confirmed a falldown on regulated forest lands. The drop was from 68 million to 59 million m^3, given the level of forest management then in place. The combined provincial and industry silviculture efforts have increased somewhat since 1985, but the Ministry still speaks publicly of a falldown and no new figures on the long run sustainable harvest have been published.

Since 1987 the province has set aside more than 1 million ha of additional land in parks, wilderness and recreation areas. In recent weeks the Premier has intervened repeatedly in the land use controversy to promise additional re-allocation of licensed land. The most significant is the declaration that clearcuts will not be allowed where they can be seen from the Inside Passage. These latest pronouncements come at a time when the mandate of the Ministry of Forests has been curtailed in two ways. The first was the appointment of a permanent Forest Resources Commission tasked with policy formulation. The second was the appointment of the Clayoquot Sound ad hoc advisory committee to which is delegated the decision making authority over the use of a large section of licensed forest land on the west coast of Vancouver Island.

In short, the implied strategy of the provincial government is to sharply reduce the availability of timber and thereby threaten the employment base for the largest economic sector in B.C. This has all been done without strategic thinking, without targets, and with a noticeable erosion of accountability by the senior officials in the Ministry. Priorities have shifted markedly, away from sustainable development and toward preservation. I do not question the governments authority to make such a policy, but I do question the prudence of doing so without any attempt whatever to weigh the costs.

INDUSTRY IMPLICATIONS

The forest industry also has a role to play in strategic planning, both individually and collectively. What they

are doing as a group is not known. It seems likely, however, that the various regional and sectoral trade associations are following their respective interests, with no cohesive representations to Victoria on long term forest management goals and on land use more broadly.

An interested observer must conclude however that they are neither thinking nor speaking out publicly in strategic terms. For instance, there is no persistent call for expanded forest yield by means of intensive silviculture. And there is no considered public response by industry to the governments new enthusiasm for preservation of old growth timber and for constraints on clearcutting.

Industry is not popular with the average citizen at the present time, and when this is coupled with an adversarial press, they are understandably reluctant to speak out. Moreover, their leaders are generally represented by "bottom line" people who focus better on near term problems. While giving lip service to forestry principles, they tend to ignore the longer run "top line" of resource availability.

There are of course exceptions to the above characterization of senior industry officials. Unfortunately the general rule is still valid. Industry and the forestry profession which serves it are very fuzzy about chronology. They tend to confuse short run operational planning with long run strategy. This has always been a mystery, raised as I was in an agricultural tradition where land conservation was the guiding principle. If Peter Drucker is correct, and strategic planning is the entrepreneurial skill, then we should anticipate some positive attitudes to develop soon toward strategic thinking.

BACK TO MIXEDWOOD FORESTS

We are not limited to what Nature has given us. It is feasible to intervene in these existing northern forests in order to:

- enhance the yield
- move some stands forward in the harvesting queue
- reduce the costs of harvesting, transportation and processing
- increase product values
- reduce the risks from insects and fire, as well as from timber deficits.

At the same time we are achieving these timber goals, we should be able to improve the harvest of fish and wildlife, to ensure that environmental guidelines are met, and to concede some additional land to preservation. Our success or failure along these lines will reflect the kind of policies we formulate in the immediate future.

The first policy implication grows out of my conviction that mixedwood forest management may be ideally suited for small entrepreneurs. I would like to see a higher priority for smaller businesses. The experience accumulated with small private forest owners in central and eastern Canada, and in northern Europe, suggests that mixedwood forest management in B.C. should be directed in greater measure toward this group. So far the small forest operator has only token recognition.

The second policy recommendation deals with the silviculture mix. Let's see what we can do to ensure a balanced program, and ensure that priority is given to timber stand improvement. The current preoccupation with regeneration loses sight of the opportunities to greatly enhance the value of existing stands which are over 20 years of age.

The third policy should declare that integrated management is the first consideration for the northern mixedwood forests. So far the environmental groups have not focused on the northeast of B.C., but they are headed your way. It is timely to incorporate the "soft green values", as Professor Paivio Riihinen (1989) phrases it, and to give equal weight to non-timber elements.

The fourth recommendation calls for an emergency effort in forestry science devoted to growth and yield of managed stands, as well as to the appropriate treatment for middle aged natural stands. In order to implement the right management regime it will also be essential to prepare a management inventory which describes more adequately the existing timber as well as the soil and site capability.

Finally, the FRDA renewal negotiators must re-examine budget allocations to reflect the four items just listed. Some would argue that we have already knocked down too much valuable deciduous and mixed wood forest in the name of NSR rehabilitation.

CONCLUDING COMMENT

The managers of northern mixedwood forests will have to fight for their place in the sun. The budget patterns have always given preference to the larger and immensely valuable old growth forests of softwood species. It will not be easy to shift the mindset of previous decades. A substantial re-tooling of forestry professionals in the north is called for, and probably changes in the forestry curriculum.

Perhaps the best place to start is a strategic plan for the northeast corner of British Columbia where the majority of this province's mixedwoods are located. That would make a manageable pilot project, on which similar ones could be based elsewhere in Canada.

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INVENTORY: PROBLEMS AND HOW THEY MAY BE SOLVED

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ABSTRACT

The Commercial Forest Zone in Saskatchewan and the forest industry dependent upon it are described. The present forest inventory is discussed, and improvements are proposed to facilitate the management of the mixedwood component of the forest.

INTRODUCTION

Although the Provincial Forests in Saskatchewan comprise some 54% of the total Provincial area of 652 thousand square kilometres, only 10% is productive forest land in the Commercial Forest Zone. This Zone is bounded by the Churchill and Clearwater River Systems in the north and by agricultural lands in the south (see Figure 1). Mixedwoods make up about 21% of the productive forested lands. The forest economy in Saskatchewan is not large compared to several other Provinces; nonetheless it contributes about 500 million dollars to the economy (including the new Weyerhaeuser Canada Ltd. paper mill in Prince Albert). In the past the industry was nonintegrated, in that there was a softwood industry and a hardwood industry. That past style is changing rapidly. Weyerhaeuser Canada Ltd. now uses a balance of hardwoods and softwoods in the pulpmill in Prince Albert; a proposed hardwood pulpmill on the west side of the Province will fit very nicely with the present softwood sawmill owned by NorSask Forest Products; and a number of integrated options are being considered for the east side. All of these developments should result in improvements in the management of the mixedwood portion of the forest.

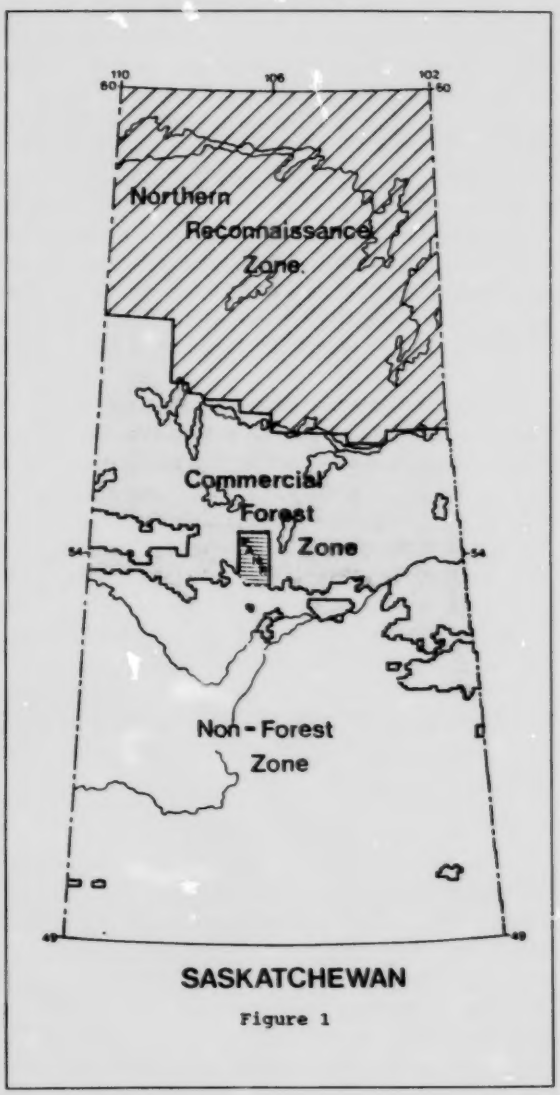

Figure 1

BACKGROUND

Saskatchewan now is beginning the second cycle of the third general forest inventory of the Province. These general inventories cover the time periods from 1947-1956, 1957-1976, and 1977 to the present, with each inventory becoming more detailed than the previous one. Changes from one inventory to the next included larger map scales, increased classification categories, increased number of field samples, and improved data management. Although no major changes are being made in the physical side of the present inventory, data management should improve considerably through the use of a recently acquired large scale geographic information system.

INVENTORY SUB-SYSTEMS

The development of a forest inventory amounts to a juggling act, the balls in the act being: classification systems, remote sensing technology, field sampling designs and methodology, data management, and of course, the money available to combine all these. The selection of combinations becomes somewhat simpler if management objectives are known. Unfortunately, these objectives are not always clear, at least in forest inventory terms. (For example, a forest manager very well may not understand the implications of a change in photograph and map scale ratios, particularly in terms of cost). In 1977, the general objectives were to create an inventory that would be useful in mapped form for daily forest operations, and in numeric form for regional timber supply analyses. Largely these objectives were and continue to be met.

Classification System

It is unlikely that the Saskatchewan system is much different from those in other jurisdictions. Briefly, strata recognized are:

Species associations	(18)
Height classes	(5)
Crown closure classes	(4)
Year of origin classes	(18)
Soil drainage classes	(13)
Soil texture classes	(8)
Productive non-forested classes	(4)
Non-productive classes	(several)

The first three classes form the basis for the field sampling, but all classes are mapped. A typical forest cover type label is illustrated in Figure 2. Key additions to the forest inventory in 1977 were the year of origin, drainage, and texture classes. The former has proven invaluable, while the latter two have yet to be proven as estimators of soil productivity.

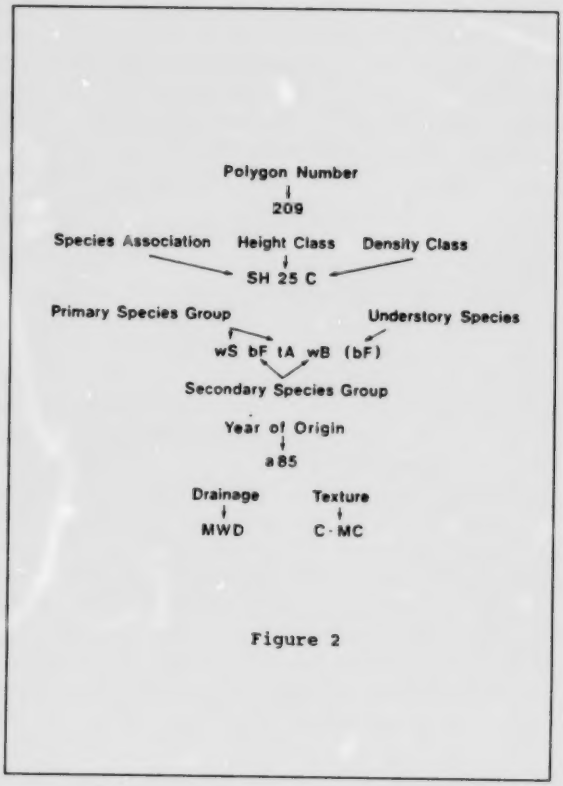

Figure 2

TABLE 1.

Comparison of Standard Error Estimates
(Percent of mean volume, 95% confidence)

Cover Types	Hardwoods	Softwoods	All Species
SH20B Spr. tA	27.5	18.4	15.9
SH20C Spr. tA	19.4	11.3	8.1
SH20B jPtA	58.0	42.2	34.9
SH20C jPtA	27.3	17.2	15.0
HS20B tA Spr.	27.1	42.1	12.6
HS20C tA Spr.	14.6	14.0	8.5
HS20B tAjP	31.4	84.1	24.6
HS20C tAjP	28.3	52.0	17.3

Source: C-10 Stand and Stock Tables

Mixedwood classes are: spruce-aspen mixtures, aspen-spruce mixtures, black poplar-spruce mixtures, pine-aspen mixtures, and aspen-pine mixtures, all with the attendant height and crown closure combinations. All 100 of these combinations occur, but only about three-quarters are in excess of 1000 ha within the Commercial Forest Zone.

Remote Sensing and Mapping

Again, Saskatchewan uses techniques similar to the rest of Canada. The basic remote sensing tool is aerial photography; the pictures are interpreted using stereoscopes; base maps are prepared; and the interpreted information is transferred manually to the base maps. Areas are determined using dot grids and the information is stored on computer. Pertinent technical data are:

Photography
- Scale ratio: 1:12500
- Format: 23 cm X 23 cm contact prints
- Film type: modified infrared black and white

Maps
- Scale ratio: 1:12500
- Projection: Universal Transverse Mercator
- Graticule: 10 km X 10 km (80 cm X 80 cm)

Computer data base
- Geographic resolution: 0.4 ha
- Magnitude: 300 megabytes (plus 600 megabytes backup)

Although some jurisdictions seem to be achieving value from satellite imagery, it has seen few applications in forest inventory in Saskatchewan. It is unlikely that this will change in the near future, since the computer systems to process the data and the necessary expertise are both lacking.

Field Sampling Designs and Methodology

Generally, Saskatchewan has always used some form of systematic stratified random sampling (systematic in that the plots are more or less equidistant apart within a stand; stratified in that the stand earlier has been placed in one of the available strata; and random in that the specific composition of the stand was not known beforehand). For the present forest inventory, the field season in 1977 was used to test several sampling methodologies. The principal measure of sampling efficiency was standard error of the estimate of average gross merchantable volume from a similar number of samples. The cost of each method had to be judged subjectively since data for several of the methods was collected simultaneously. A total of 251 plots were established, measured, and analyzed. The methodology selected was a variation of Probability Proportional to Prediction, or 3P sampling. This methodology was implemented in 1978 and has been in use ever since. The total number of sample plots established to date are about 24,060, of which 7,070 (29%) are in the mixedwood species associations. Based on average volume per stratum, the standard error of the estimate for well stocked mixedwoods is similar to those in the "pure" species associations. However, when looking at the similar statistic for either the softwood or the hardwood component, the percent standard error is higher (see Table 1).

For all eight forest cover types the standard error is less for all species combined than for either the hardwood or softwood components. Applying the "all species" value to either component will lead to serious under-estimates of confidence limits and required sample size.

Data management Systems

To all intents and purposes, the arithmetic of forest inventories has not changed over the years - estimates are made on a per-unit-area basis, area units are determined through sampling or planimetry, and the values are multiplied together resulting in an overall estimate of the value of interest (volume, basal area, etc.). In the first Saskatchewan forest inventory the data management system was entirely manual; in the second inventory the system was built around mechanical calculators; the present system couldn't function without fairly heavy duty computer power. Compilations that took months in the first inventory now take minutes. Also in the past, mapping systems and data analyses systems were almost completely separate. With the advent of geographic information systems, that no longer is the case. As the forest inventory data base (maps and numbers) is loaded on computer, the simultaneous management of both sets of information becomes not only possible but essential.

A very appealing feature about having easy access to computers is that it now is possible to carry out extremely complicated mathematics very easily. For example, the forest inventory in Saskatchewan does not carry statistics describing sampling error, because not long ago it simply was impractical to make and apply the various complex calculations. Foresters even today do not appear to be making use of the computer power available to them for data manipulation and management.

INTERFACE WITH OTHER SYSTEMS

At the present time, the major interface between the forest inventory and the rest of Forestry Branch is with Timber Management Section for timber supply analyses. However, these analyses only include areas that currently are forested. The missing interface is with Silviculture Section for data on the replacement forest. The annual planting program (both government and industry) is about ten million trees, with plantation assessments being carried out at one- and five-year intervals. The results of these assessments are not always conclusive and, in any case, are not being reintroduced onto the forest inventory data base. Hence, as the inventory is updated for cutovers etc. the apparent remaining timber supply diminishes.

PROBLEMS AND SOLUTIONS

There are any number of ways to improve a forest inventory. With the increasing importance of mixedwoods as available timber supplies, five problems in particular deserve attention.

Classification System

The present system in Saskatchewan is too broad to adequately examine species composition, both in terms of proportions of species present and the specific species that may or may not occur. A solution is to add more categories of mixedwoods to the system; for example, it would not be difficult technically to create two spruce-aspen classes differentiated by levels of stocking by species. This action would increase the number of forest cover types, which in turn leads to increased costs for every step in the inventory process. For example, at 75 new cover types and 20 field samples per type, field work alone could cost an additional $150,000.

Remote Sensing and Mapping

The classification of mixedwoods is difficult at best on standard aerial photography. Foresters must be prepared to experiment and if necessary justify spending extra money to improve their photo interpretation capabilities. For example, colour aerial photography is about twice as expensive as black and white.

Sample and Model Errors

These types of errors are inherent throughout the numeric analyses portion of the inventory system, ranging from the model used for stem analysis to the sample errors associated with field samples. All such errors are calculable and must be carried through to the final timber supply analyses where they can be expressed as confidence limits.

Data Management

Forest data management today is almost entirely dependent on the use of computers; however, foresters cannot realistically be expected to be experts in designing and running computer systems. Therefore, it is incumbent on all forestry agencies to ensure that they have access to a high level of this type of expertise. For example, sending a forester to a course on FORTRAN simply is not adequate.

Silviculture Data

In Saskatchewan, there is no linkage between the Silviculture information (such as it is), the inventory data base, and hence the timber supply analysis. Two solutions are necessary. Firstly, the data must be improved to a point where decisions can be made - for example: stocked/not stocked, free to grow or not, species present, and so on. At present, millions of dollars are being spent with unknown results. Secondly, that data must be linked back into the inventory data base thus making it accessible for timber supply analyses. Unless these solutions are put in place the estimate of the long run sustainable yield will continue to be under-estimated, with the potential losses to the Saskatchewan economy.

SUMMARY

With the increasing interest in the management of the mixedwood component of the Saskatchewan Provincial Forests, several specific improvements can and should be made to the forest inventory. Five of these are:

- Increase the number of mixedwood classifications to reduce the variation within the present classes.
- Experiment with varieties of remote sensing, particularly aerial photography to better interpret mixedwood stands.
- Incorporate all sources of model and sample errors into confidence limits for timber supply analyses.
- Ensure that a high level of computer systems expertise is available for all data analyses.
- Ensure that sufficient data for decision-making is available to silviculturists and that this data is incorporated into the timber supply analyses.

DYNAMICS OF BOREAL MIXEDWOOD ECOSYSTEMS

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Mixedwood ecosystems play a very important role in the dynamics of the boreal forest. Nearly every successional pathway in the boreal forest includes a mixedwood phase. Understanding the dynamics of these mixedwood phases allows insight into how the mosaic of different forest cover types have been established. It also allows forest managers to speculate as to how they might successfully establish or manipulate mixedwood forests in order to achieve maximum forest productivity at relatively low cost.

An important prerequisite to understanding the dynamics of mixedwood forests is understanding the autecology of the main tree species present. Table 1 compares some of the autecological characteristics of the main boreal tree species. All species regenerate after disturbance but the level of disturbance and presence or absence of an adjacent undisturbed seed source controls which species are favoured. Light disturbances which do not expose mineral soil favour deciduous species which regenerate by suckering from disturbed root or stem sections. All species regenerate well after disturbances which expose large areas of mineral soil. Lodgepole pine (*Pinus contorta*) and black spruce (*Picea mariana*) will seed into disturbed areas in the absence of an adjacent seed source. This is due to the large amounts of seed which are released from their cones during or soon after a disturbance. In the case of white spruce (*Picea glauca*) the presence of an adjacent undisturbed seed source is required as seed from the disturbed stand is destroyed during the disturbance. This would suggest that white spruce would have a difficult time getting established yet it is one of the more dominant species in the boreal forest. The reason that it can become dominant is that it regenerates well under a canopy.

As well as taking advantage of a situation which other species are not able to, white spruce regeneration draws some benefits of the environment beneath a canopy. Soil temperature extremes, and drying out of the upper soil layers are both reduced under a canopy. In addition, a deciduous canopy enriches the soil through yearly nutrient rich leaf fall.

The most common boreal mixedwood type found on upland sites is trembling aspen (*Populus tremuloides*)/white spruce. Two situations dominate in this type. Either the white spruce regenerates within a few years of the aspen or after the aspen stand is approximately 20 years or older. The first situation requires a relatively severe disturbance, usually a hot burn, to expose mineral soil. Then, a good crop of viable seed from an adjacent live seed source is required so that regeneration occurs before aspen stems completely dominate the site. Lack of viable seed within the first few years limits regeneration because available microsites are taken up by aspen or other aggressive pioneer vegetation such as bluejoint (*Calamagrostis canadensis*). Aspen density can often be up to 80,000 stems/ha in young stands in the first five years (Les Herring, pers. comm., Aug. 1989).

After about 2-5 years density tends to decline fairly rapidly. Most aspen clumps thin down to one main stem within ten years and many of the remaining stems will themselves die off within 30 years. By age 30-40 most stands are 2000 stems/ha or less. This reduction in density of aspen provides another opportunity for spruce to seed in. Apart from aspen density being lower, by this time the understorey vegetation has diversified. A portion of the space is occupied by relatively non-competitive low growing herbs such as bunchberry (*Cornus canadensis*), trailing raspberry (*Rubus pubescens*), and creamy peavine (*Lathyrus ochroleucus*). Given a good seed year and a relatively moist summer spruce is able to regenerate on any microsite which is not occupied by an aggressive competitor. Favoured microsites are rotting wood and exposed mineral soil, but seedlings will also establish in leaf mould and to a lesser extent in moss. Once spruce has established itself, density generally increases as stand age increases. In the absence of a major disturbance it will eventually dominate the stand.

The most common mixedwood type found on lowland alluvial deposits is balsam poplar (*Populus balsamifera ssp. balsamifera*)/white spruce. This ecosystem generally originates from periodic flooding. Flooding of these stands does not kill Balsam poplar and it leaves behind a mineral soil seedbed which is ideal for spruce regeneration. Spruce grows very well on these wet rich sites and in the absence of major flooding will eventually dominate the site.

Less common in the boreal forest are mixedwood stands involving aspen and lodgepole pine. These stands generally occur on drier upland sites. Lodgepole pine is very well adapted to fire and often replaces itself after fire but will sometimes regenerate in mixtures with trembling

aspen. The amount of lodgepole pine in an existing mixedwood stand may increase or decrease after disturbance depending upon the severity of the disturbance and the climatic conditions after the disturbance. If the disturbance does not expose mineral soil to an extent that pine can seed in, the component of pine will be reduced. This often results in an aspen dominated stand with a few lodgepole pine veterans which survived the disturbance. A more severe disturbance which exposes an significant amount of mineral soil favours a more mixed situation with a higher component of lodgepole pine.

Other mixedwood forest types are uncommon and of generally small extent. Willow (*Salix spp.*)/spruce and paper birch (*Betula papyrifera*)/ spruce are the most notable of these. Willow spruce mixedwood generally occurs on very wet sites with fairly thick organic layers. Mineral soil exposed around old stumps or root throws provide an adequate seedbed for spruce regeneration. Paper birch/ spruce mixedwood stand are established in a similar manner to aspen/spruce mixedwood stands.

An understanding of the dynamics of mixedwood ecosystems not only allows us to better manage these ecosystems it also offers some interesting forest management possibilities, particularly for areas where coniferous seed sources have been removed. One such example is the underplanting of 30-40 year old aspen stands. Judging from the success of natural spruce at regenerating under stands of this age it is apparent that the environment is suitable for spruce establishment. By planting, spacing can be controlled enabling easier protection of the spruce during stand entry for harvesting of the aspen overstory. If the aspen were to be removed from the stand at 60 years, the spruce would be 20-30 years old. Spruce of this age would be easily seen and if inter-tree spacing was relatively large (eg. 4-5 m) they would be relatively easy to protect. Spruce of this age should release very well and the relatively large inter-crown space would allow resprouting of aspen to fill in the gaps. A mixedwood stand would then be established which is fully occupied by a mixture of aspen and spruce. When harvested in another 60-80 years this stand would yield a high combined volume. This is one example of taking advantage of the natural dynamics of mixedwood ecosystems. In order to manage boreal forests efficiently, forest managers must except the natural dynamics of the ecosystems and attempt to adapt their forestry practices to them.

TABLE I. Some autecological characteristics of the main tree species occurring in boreal mixedwood forests.

Characteristic	Species				
	Aspen	Balsam Poplar	White Spruce	Lodgepole Pine	Black Spruce
Ability to regenerate under a canopy	L	L	H	L	L
Ability to regenerate after light disturbance	H	H	L	L	L
Ability to regenerate after heavy disturbance	H	H	H	H	H
Susceptibility to damage by fire	H	L	H	H	H
Nutrient content of leaf litter	H	H	L	L	L
Juvenile growth	H	H	L	M	L
Palatability	H	H	L	M	L

Each characteristic is rated L - low, M - moderate, or H - high for each tree species.

REGENERATION IN THE MIXEDWOODS

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ABSTRACT

With increased aspen utilization, expansion of mixedwood harvesting and arrays of decisions in silviculture planning, regeneration in the mixedwood stands is becoming complex and exceedingly challenging. Diversity of management objective and the lack of biological solutions and resources for successful reforestation contributed to silviculture difficulties on spruce/mixedwood sites. The challenge is how to improve conifer regeneration and realize the productivity potential of mixedwood sites.

We examine silviculture alternatives and related stand development patterns in the scenarios of managing mixedwoods for softwoods, mixed woods for mixedwoods and mixedwoods for hardwoods and how these tender to potential improvements in regeneration strategies. We need to master a wide range of silviculture options. This demands that we learn more about the complexities and dynamics of mixedwood ecosystem and apply improved knowledge to both extensive and intensive management.

INTRODUCTION

The last 10 years has seen careful reappraisals of the regeneration status in Boreal forest and in mixedwoods (eg. Weetman 1982,1987,1989; Benson 1988; Yang and Fry 1981).

At the 1988 Mixedwood symposium (Samoil 1988) several speakers addressed the difficulties of regeneration and the need for more intensive establishment of conifer plantations on mixedwood sites (Day and Bell 1988; Drew 1988). There are two messages re-occurring in these reviews:

> "The wood growing potential of mixedwood sites is not currently being realized" and
> "There is a gradual shift to increasing hardwood component on mixedwood sites".

In a simplistic view it appears that foresters lag behind in maintaining productivity of the resource or it could even be suggested that regeneration specialists are to be blamed. On the other hand, many of us may feel that forest managers have clouded the issue of regeneration in mixedwoods by the conifer bias, emphasis on survival, overoptimistic expectations and viewing regeneration as an isolated process, when in reality it should be viewed as the critical first step in the silvicultural system.

There have been several issues suggested for the regeneration problems:

1. The prevailing attitude to regenerate extensively
2. Not enough money for the required work and
3. The lack of workable biological solutions for the establishment of regeneration that would maximize growth.

The first two issues are related to forest management strategies and policies, and have been reviewed superbly by Weetman (1987,1989), Benson (1988), and Baskerville (1982). The last issue, the lack of biological solutions, is broader and more contentious. We would like to challenge and examine regeneration problems in this context and offer some approaches to regeneration strategies.

REGENERATION STRATEGY MUST BE RESPONSIVE TO MANAGEMENT OBJECTIVES

Regeneration serves a purpose; it is a component of silvicultural systems and it must reflect management objectives.

Changes in utilization of the forest resource have been the driving force behind recent new approaches and improvements to traditional mixedwood regeneration. The key change and advantage of this new era is the acceptance of aspen as a commercially important and valuable species for regeneration. Thus mixedwood cover types can be regenerated under three management scenarios: mixedwoods to hardwoods, mixedwoods to softwoods, and mixedwoods to mixedwoods, and the regeneration strategies and silvicultural options vary accordingly.

ASPEN REGENERATION SILVICULTURE IN MIXEDWOODS FOR HARDWOOD PRODUCTION

With the acceptance of hardwood production on mixedwood sites, a silvicultural system of clearcutting and even-aged stand management can be readily used for aspen renewal and management. The reproductive and silvicultural characteristics of aspen have been reviewed by Davison et al. (1988), Debyle and Winokur (1985) and Doucet (1989).

Aspen content in the parent mixedwood stand is the major factor influencing aspen regeneration density. Aspen basal area in the parent stand as low as 2-5 m^2/ha (Perala 1977; Doucet 1989) and volume as low as 26 m^3/ha (Stoeckeler and Macon 1956) can produce adequate aspen stocking after clearcutting. Similarly, about 25-50 well-distributed trees/ha may produce over 10,000 suckers/ha.

On 15-year-old pine cutovers in the Grande Prairie region in Alberta we found that a single parent tree may restock a 400-500 m^2 area with suckers (Navratil and Bella 1988). This observation compares well to the above estimate of 25-50 aspen trees/ha to adequately regenerate the area.

The essential prerequisite of aspen regeneration systems is clearcutting. A partial cut with a residual canopy can severely reduce aspen regeneration density. The negative effects of such a canopy are threefold: a) maintenance of apical dominance, b) reduced soil temperature, and c) reduced light. A residual canopy allowing 50% sunlight has been found to reduce suckering density tenfold, from 98,000 to 7,400 stem/ha (Baker 1925). As little as 1-1.5 m^2/ha basal area of residuals may slow sucker growth by 40% (Perala 1977). Thus, for example, in mixedwood stands with a considerable component of balsam poplar the residuals should be cut to optimize sucker growth and development.

Mixedwood stands as compared to pure, upland aspen stands, require more attention to aspen reproduction strategy. Low density sucker regeneration frequently develops after harvesting mixedwood stands for several reasons (Navratil et al. 1989; Peterson et al. 1989b).

Mixedwood cover types occur over a wide range of the moisture regimes, soil texture and thickness of organic layer, all of which affect density of aspen regeneration and aspen growth. Often on the most productive mixedwood sites, a thick duff layer, rise in the water table after harvest, low soil temperature and the invasion of alder and willow competition may hinder aspen regeneration. On such sites, the balsam poplar component in regeneration often increases compared to the original stand. Aspen roots have a low tolerance for high soil moisture content, and waterlogging after harvest can substantially reduce suckering (Yang and Fry 1981; Bates et al. 1989). Low soil temperature tends to reduce suckering capacity of aspen (Zasada and Grigal 1980; Peterson et al. 1989).

In this context, an ecologically based site classification that also incorporates soil moisture dynamics may be particularly useful in mixedwood management, because aspen productivity and stand response to logging, site preparation, and regeneration practices are all site related and predictable (Corns 1988).

Insufficient aspen stocking and patchy aspen regeneration in mixedwood cutovers, particularly on mesic sites, can frequently be ascribed to soil compaction and root disturbance from logging. Aspen roots producing suckers are in the very surface layers of the soil, 0-8 cm from the surface, and are vulnerable to mechanical damage. Scheduling of harvesting on sensitive sites and integrated one-entry harvesting of both species will be required to minimize damage and secure uniform regeneration.

The recent upsurge in logging mixedwood cover types coupled with aspen utilization has much improved the perception of aspen reproduction. Forest managers have come to realize that desirable aspen regeneration may not be free after all, and that aspen regeneration may need to be encouraged (Smith 1988, 1989) as is conifer regeneration.

Rehabilitation of high-graded and overmature mixedwood stands for hardwood production

A special aspen regeneration problem and the opportunity to substantially improve aspen productivity exists in high-graded mixedwood stands where conifers have been removed, and in overmature stands. Such stands are characterized by irregular, unevenly-aged regeneration and stand structure, and by heavy invasion of hazel and mountain maple on dry and well-drained sites and by willow and grasses on moist sites. For example, in Saskatchewan about 182 000 ha of mixedwood stands have reached such a decadent stage. Rehabilitation of these stands to full production is a challenging task that will require testing of stand rejuvenation methods (Jones 1987; Perala 1983) supported by appropriate management guidelines and incentives.

Trend toward short-rotation management

Aspen renewal and regeneration management under an even-aged silvicultural system will tend toward rotations of 40-50 years or shorter under special conditions (Fig.1). Techniques for producing aspen in short rotations has been developed (Perala 1979; Stiell and Berry 1986; Ek and Brodie 1975). At present there is a lack of experience with aspen rotations as low as 50-60 years and with intensive aspen management in the Boreal forest. The experience from Minnesota and elsewhere shows that aspen can be managed to maximize the benefits to wildlife by manipulating cut-block sizes, age-class distributions, edges, habitat and browse to support wildlife species. One factor that could encourage relatively short rotations is the culmination of mean annual increment (MAI) of 55 years on good sites and 65 years on poor sites (Plonski 1974). Views may differ about the age at which there is culmination of MAI in aspen. The B.C. Ministry of Forests currently assumes culmination of aspen MAI at age 100 (Peterson et al. 1989a).

REGENERATION OF CONIFERS ON MIXEDWOOD SITES

Several speakers at the 1988 Northern Mixedwood Symposium pointed out two main challenges of conifer regeneration on mixedwood sites:

- to recreate mixedwood stands with a minimum of spruce as a maintenance measure, and
- to create and maintain some pure conifer stands.

The same concerns have been identified as important stand-level mixedwood problems in the recent survey of forest managers (Peterson, et al. 1989b) in the Prairie Provinces.

There is a strong perception that conifer regeneration on mixedwood sites, primarily white spruce, is falling behind and as a result, declines in productivity of conifer species and in projected Annual Allowable Cut (AAC) are expected to occur in the future. On the other hand, Day and Bell (1988) suggest that coniferous species, particularly white spruce, may be far more productive than aspen when managed under intensive plantation regimes.

White spruce bias and fall-downs in conifer renewal

Historically, white spruce has been considered the most useful and desirable species in the mixedwood zone

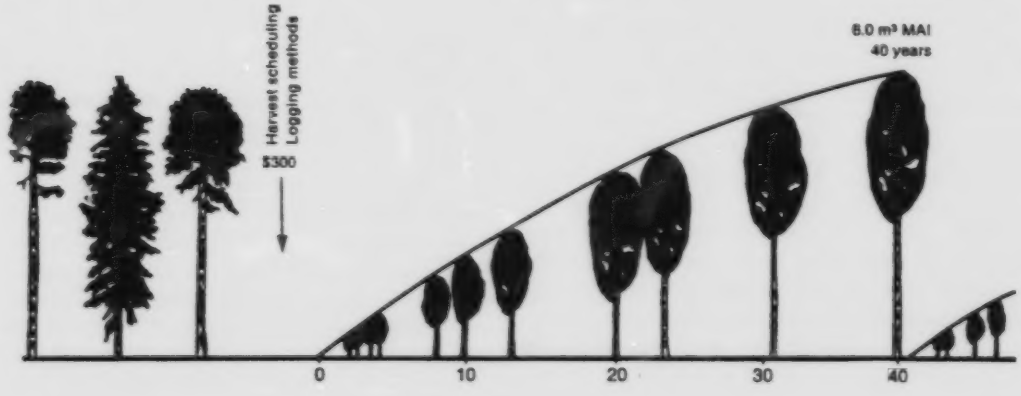

Figure 1

because of its impressive size, high yield and valuable wood.

There is obviously some bias in this. The fact is that white spruce has ranked high due to volume in the original stands, market value, and its contribution to wildlife and aesthetics. Opinion differs as to whether or not it will retain, or should retain, the same ranking in the future.

White spruce has been the primary regeneration species on mixedwood sites. In the period 1980 - 1985 the total area planted to white spruce in Canada amounted to 430,236 ha (Kuhnke 1989). In some areas and provinces the entire white spruce planting programs have been designated for mixedwood sites.

Yet, over the last several years provincial surveys have indicated serious fall downs in white spruce renewal and particularly in growth (Rannard 1988; Little 1988; Drew 1988). In Alberta up to 50% of the reforested areas on cutovers 10 years and older were found to be reverting to high density hardwoods, with another 14% developing as mixedwoods (Henderson 1988). Surveys also show that although density and survival may be adequate, the age and the height of crop trees is not consistent with cutblock age. Many crop trees suffer from heavy competition resulting in growth losses and there tends to be a continuing cycle of ingress and mortality.

The reasons commonly given for the fall-down in white spruce regeneration are repetitious across the mixedwood zone; biologically inappropriate site preparation, grass and shrub competition, aspen competition, impeded drainage, hare damage, and stock quality not matching site attributes. There is an underlying influence of site common to all of the listed impediments. It is evident that the prerequisites of successful white spruce regeneration are knowledge of the site and use of regeneration prescriptions reflecting the site attributes. The integration of the site classification systems into silviculture prescriptions has been done in the recently legislated Pre-Harvest Silviculture Prescriptions in B.C. (Wyeth 1989).

This is not, however, a simple task. In our view there is not sufficient information available on the establishment and growing requirements of white spruce to take into account site variations and appropriate site-specific treatments. Regeneration treatments are applied more often on the basis of experience and intuition than of detailed documented knowledge. Much site research will be required to provide the foresters with the knowledge base necessary to select the best regeneration treatments and prescriptions. It is also felt that separate guidelines may be required to meet the specific needs of regeneration planning on complex and diversified sites of the mixedwood zone (Peterson et al. 1989b).

A few experienced foresters who have taken the time and effort to appreciate local soil and environment conditions have been successful in establishing tracts of white spruce plantations (G. Marek Pers. Comm.). With the help of site classification guides (Corns and Annas 1986; Jones et al. 1983; DeLong 1988) available for large parts of the mixedwood zone there is now the opportunity to extrapolate local experience to similar sites and to consolidate fragmentary knowledge from numerous reforestation trials across the mixedwood zone.

Planting micro-sites and site-specific influences on regeneration may override the major site units as defined by site classification systems. Many good papers are available on interaction of site, micro-site, vegetation management and plantation performance of white spruce (Sutton 1975, 1984, 1985, 1988; McMinn 1982, 1985; Herring 1989). Work on consolidation of site classifications for silviculture prescriptions on mixedwood sites is needed urgently and such classifications should be tied into ratings of competition, frost damage and browsing.

Intensive management of conifer plantations

Realization that extensive regeneration systems will not give sufficient conifer survival and growth has lead the managers to see little option but to intensify silvicultural practice. The application of more-intensive regeneration systems for white spruce has been advocated for Alberta's reforestation strategy as described by Drew (1988) and is being considered in other provinces Rannard (1988). Weyerhaeuser Canada Ltd., Saskatchewan is currently addressing white spruce culture by intensive site preparation and multi-entry cleaning and tending of regeneration (R. Orynik Pers. Comm.).

A crop plan based on density models and prescriptions for white spruce plantations on mixedwood sites was discussed by Day and Bell (1988). Their plan includes preharvest hardwood poisoning, heavy site preparation planting large transplants, two weedings with herbicides, and successive multiple thinnings.

The potential of intensive plantations for securing and increasing conifer yield is high and as such it must be considered as one of the viable regeneration strategies on mixedwood sites (Drew 1988).

There are, however, several important prerequisites for high yeild white spruce plantations: improved knowledge of site selection and site productivity, high front-end

investments, commitment to follow-up treatment, and improved knowledge of pest and physical damage management such as wind and snow.

There is little known about the ecological suitability and growth of white spruce in pure, even-aged plantations and there are uncertainties about pest and damage risk. We do not have many white spruce plantations where we can knowledgeably assess long-term productivity and risks.

White spruce has constraints that may limit its broad use in intensive plantations. It occupies a narrower range of sites than other species, eg. black spruce and is also more susceptible to frost. Black spruce has the ability for rapid juvenile growth and unlike white spruce is not considered a slow starting species.

Other species such as tamarack on hydric and subhydric sites, Siberian larch and lodgepole pine on mesic and submesic sites, may equally be considered for high production intensive plantations. Superior growth of larches as compared to white spruce found in the species testing program of the Alberta Forest Service (Table 1) demonstrates the potential of these species on mixedwood sites, though, as for white spruce, little is known about their long-term productivity and risks.

The role of pines in plantations on mixedwood sites should also be more vigorously explored. Lodgepole pine is easy to establish by planting, has rapid early growth, and competes well with aspen (Vyse and Navratil 1984). On average, planted lodgepole pine reaches a height of 1 m in 6 years, as compared to 11 years for white spruce on mixedwood sites in Alberta (Alberta Forest Service, unpublished data).

The choice and regeneration of conifer species may be influenced by climatic warming. Specialists stress sensitivity of the Boreal forest to warming and hypothesize that a warmer and drier climate would hinder conifer production and encourage the domination of hardwoods (J.P. Kimmins as quoted in Peterson et al. 1989a).

The potential effect of climatic warming on aspen productivity and regeneration was differentiated into three zones in the prairie provinces and British Columbia; negative effect on aspen productivity, positive effect on aspen productivity, and no effect (Navratil et al. 1989). For this reason alone the diversification of species composition including an increased component of lodgepole pine should be favoured in plantations on mixedwood sites.

Commitments to plantation management

A regeneration and silviculture system for intensively managed conifer plantations (Figure 2) requires intensive, "high cost" establishment and commitment to crop tending, thinning and protection regimes. The relevance of commitments is real and essential; the initial investments need to be secured by completing tending and thinning treatments. Furthermore, in managed, even-aged conifer stands many conditions are different from those of natural mixed stands and the stand's stability and resistance to environmental and biotic changes are affected.

Table 1. Performance of larch and white spruce on mixedwood sites. Footner Lake Forest, Alberta[a]

	Siberian Larch			Tamarack			White Spruce		
	Total ht.	Ht. increment Mean ann.	Current	Total ht.	Ht. increment Mean ann.	Current	Total ht.	Ht. increment Mean ann.	Current
9 year-old Plantation	362	40	85		N/A		135	15	33
10 year-old Plantation	340	34	66	230	23	32		N/A	

[a]source: N. Dhir, Alberta Forest Service
N/A = Not Available

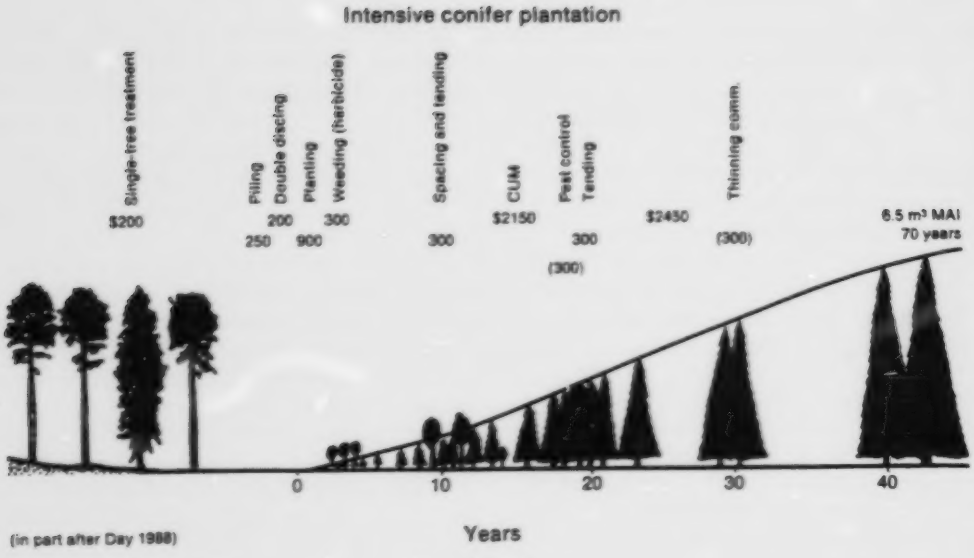

Figure 2

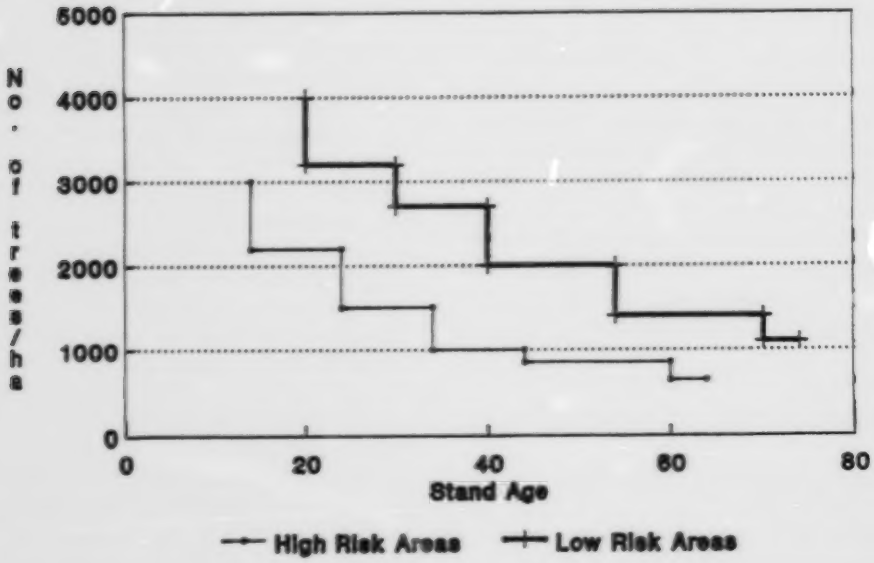

Figure 3. Thinning regimes to minimize wind and snow damage in Norway spruce stands on high productivity sites (adapted from Perez and Chroust 1988)

Wind and snow damage hazard increase significantly in managed stands. In many countries with large areas of even-aged managed stands of conifers, wind is a constant risk. In Sweden, 75% of the annual mortality, which amounts to 11% of the total annual increment of the country, is attributed to damage by wind and snow.

In central Europe, for example in Czechoslovakia in the period 1976-1985, salvage cuts in conifer plantations due to damaging agents amounted to 62% of the total AAC from which wind and snow damage accounted for 46% and 18% respectively (Perina 1987). It is not surprising that in the countries with intensively managed conifer stands stand treatment regimes and risk rating schemes to minimize wind and snow damage are given high priority in renewal and silviculture systems.

When considering intensive conifer plantations designed for maximum production, it is essential to remember that tending and thinning regimes and wind and snow damage are directly linked. In other words, crop plans designed for maximum yield production without giving attention to stand stability could jeopardize the outcome. Timing of the first thinning and of its relation to tree height and site conditions and subsequent thinning regimes is critical. Figure 3 demonstrates thinning regimes designed to minimize wind and snow damage in Norway spruce stands under conditions of high and low risk on high productivity sites.

EXTENSIVE REGENERATION SYSTEMS FOR WHITE SPRUCE RENEWAL

In Boreal mixedwood cutovers, left untreated following harvesting, the proportion of spruce often declines, and succession is to all-aged stands dominated by aspen in western provinces or by balsam fir and aspen in eastern provinces (Yang and Fry 1981).

Extensive regeneration systems which rely on seed, either natural or artificially supplied, can increase levels of spruce regeneration, provided that they adhere to critical elements in planning and execution of the regeneration systems.

Critical elements of extensive regeneration systems

Natural regeneration of white spruce can produce excellent results on some sites. But adequate spruce regeneration is often accompanied by good hardwood regeneration (Lees 1964; Zasada and Grigal 1980) and in order to assure stands with a high spruce content from natural regeneration, weed control is necessary. The most probable use of natural regeneration systems would be in the regeneration of mixedwood stands through creation of small clearcuts or 2-cut silviculture systems as discussed later.

Planning must occur prior to harvesting in order to assure that adequate seed sources are reserved and that logging plans protect the seed source. In those situations where site preparation is not prescribed, careful consideration must be given to type of harvesting equipment to be used, in terms of its effect on surface disturbance, slash volume and distribution, and site conditions by season (eg. winter vs. summer).

Some level of flexibility for implementation and timing of operations needs to be built into a regeneration plan. For example, where seedbed preparation is prescribed to best utilize natural seed-fall, chances of more efficient use of the available seed and regeneration success are greater if the scarification is done in a year when seed will be readily available as opposed to having to do it immediately after harvest regardless of the seed crop. This option may be limited where site preparation is restricted to the winter season due to ground conditions, or when site preparation has to be carried out after the production of the seed crop and before seed fall.

Knowledge of reproductive characteristics of the species

The use of regeneration methods which depend on natural seedfall and artificial seeding requires a thorough knowledge of the reproductive characteristics of the crop species and their competitors. Without this information, most attempts to apply these systems will result in less than optimum results or in failure. For white spruce, these characteristics have been reviewed by Dobbs (1972), Fowells (1965), Zasada (1986), Burns (1983), and Haeussler and Coates (1986).

Prompt regeneration requires that a number of important factors occur simultaneously; adequate seed supply, receptive seedbed conditions and low levels of competition, particularly from herbs and grass during the establishment period. Although adequate seed crops may occur as frequently as every 2 to 3 years, intervals between good to excellent seed crops are more commonly 4 to 6 or more years. Seed dispersal distance also limits regeneration. Even though spruce seed has been found in fair quantities 100 m or more from a seed source (Dobbs 1976; Zasada 1985), it would appear that placing a seed source more than 40 to 50 m from the area to be regenerated greatly reduces the probability of obtaining natural regeneration even with the best possible seedbed conditions.

If moderate to good seed crops are to be of value for natural regeneration, distances of 30 to 40 m or less may be more desirable. Although seed crops from several years may contribute to the regeneration of an area (Gardner 1986), the efficiency of reproduction (i.e., the number of seeds required to produce an established seedling) decreases quickly as the seedbed becomes less receptive due to the development of competing (vascular and nonvascular) plants on receptive surfaces and the physical effects of annual litter fall. Although germinants are commonly found on a variety of seedbeds, mineral soil provides the best conditions for germination and survival, and regeneration from seed is generally more efficient on these surfaces. Rapid regrowth of competing vegetation, particularly grass, causes high levels of seedling mortality and often causes regeneration failure. Seedling growth is generally slow and is affected by competition and residual overstory conditions. Under the best conditions, seedlings will grow to breast height (1.34 m) in 8 to 10 years.

Harvest with no additional treatment

White spruce regeneration using this method has usually been poor throughout the Boreal mixedwood region (Lees 1964; Dobbs 1972; Jarvis et al. 1966; Fox et al. 1984; Gardner 1986). This poor success has usually been attributed to inadequate seedbed conditions and rapid development of competing vegetation following harvesting, however, inadequate seed supply is also important. There are some notable exceptions to the poor regeneration associated with organic seedbeds following harvest (Wurtz and Zasada 1988), indicating that more information is needed on the site-specific factors controlling germination and establishment on organic seedbeds. At this time, it is not possible to recommend the use of this extensive method of regeneration if prompt establishment of new seedlings (stocking goals of 50 to 60 % or greater within 5 to 10 years) is required. This appears to be true even when an adequate seed supply is maintained as in the case of the shelterwood system (Jarvis et al. 1966; Lees 1964, 1970; Zasada and Grigal 1980; Wurtz and Zasada 1988).

Assisted natural regeneration: Harvest with additional site preparation

Harvesting with additional site preparation has evolved as the method that will produce the best natural regeneration from seed following harvesting (Waldron 1966; Jarvis et al. 1966; Lees 1964, 1970; Fowells 1965; Burns 1983; Zasada and Grigal 1980; Wurtz and Zasada 1988). Stocking levels on exposed mineral soil seedbeds are frequently above 60 percent and can approach 100 percent, while stocking on adjacent untreated areas is usually 25 percent or less. Seed to seedling ratios are lower on mineral soil by an order of magnitude or more.

Site preparation can be either by burning or mechanical treatment. The general experience with burning in the case of white spruce is that only the most severe fires will result in adequate mineral soil exposure and in many cases mechanical treatment is also needed. Mechanical methods have evolved significantly during the past two decades and specialized equipment has been developed for forest sites. An important point to stress is that the use of this specialized equipment should be considered on a site by site basis. The degree of site disturbance is related to the equipment used (e.g., patch scarification, continuous strips, mounding) and this in turn affects the availability of microsites for invasion by different species.

The location of the seed source and microsite conditions are also affected by overstory treatment. Although clearcutting has become the predominant, if not exclusive method, of overstory removal, shelterwood and seed tree systems have been shown to be equally good on some sites when accompanied with site preparation (Jarvis et al. 1966; Lees 1964, 1970; Zasada and Grigal 1980; Wurtz and Zasada 1988). The application of these systems which remove the overstory in two or more cuts is often visualized as a treatment uniformly applied to the whole stand. However, in order to reduce damage to residual trees and utilize modern harvesting systems (feller-bunchers) clearcut strips of various width, with partial cutting in adjacent strips can be used as well as other combinations and cutover configurations to achieve the desired conditions (Zasada and Benzie 1970). Renewal systems which retain a portion of the mature stand are often criticized because of the loss of the residual stand to a combination of factors, such as wind, related to sudden release and damage during harvesting. Experience in interior Alaska on upland and floodplain sites has indicated that this is not a serious problem. Residual trees should be the best in the stand and not selected from the subordinate crown classes which usually have a high level of mortality following harvesting (Lees 1964). Damage to trees during harvesting should be kept at a minimum to prevent a loss of vigour and consequent increased chances of infection by disease or insect attack.

Assisted natural regeneration: site preparation and artificial seeding

This option differs from the above in that an adequate supply of seed is applied to the recently exposed mineral soil seedbed and dependence on natural seed fall is eliminated. Artificial seeding has never been widely accepted in the western boreal forest. The primary reasons have been inefficient utilization of seeds, predation of seeds by mammals, and generally poor experience when it has been attempted. New methods of seeding and protecting seeds

developed in Finland and Sweden provide promise and may make seeding a more viable option under some site conditions (see for example Dominy and Wood 1986; Putman and Zasada 1986; Youngblood in press). These methods provide a means of using seeds more efficiently and creating an environment that may improve germination and early seedling growth. A further improvement in the use of artificial seeding may be achieved if we examine and more closely mimic the natural process of seed dispersal.

REGENERATION OF MIXED STANDS FOR HARDWOOD AND SOFTWOOD PRODUCTION

There is a considerable reluctance among managers to accept mixed regeneration as an objective of regeneration strategy. Yet, despite efforts to manage for a conifer species, the end result is nearly always a mixed regeneration because of ingress of hardwood components. It is also argued that even if government policies do not encourage extensive management, the level of funding will force us to apply it to sites of average productivity (Benson 1988). Furthermore, extensive silviculture systems encourage integration of fibre and non-fibre uses and biological diversity, and for this reason alone may gain increasing support. As a result, the use of extensive regeneration methods on mixedwood sites will undoubtedly increase the amount of mixed regeneration.

The major objections to the acceptance of mixed regeneration commonly quoted by forest managers are:

- management of mixed stands is more difficult than managing pure stands,
- the serious gap in our understanding of juvenile mixed stand development and difficulties in projecting growth and yield,
- the lack of knowledge of silviculture of mixedwood stands, and
- the lack of clear guidelines for handling integrated AAC for mixed stands.

These objections have been reiterated by leading ecologists, silviculturists and managers alike. How much has our knowledge of mixed regeneration, juvenile mixed stand development and yield, and silviculture of mixed stands improved?

Concerns about yield performance of regeneration on mixedwood sites have moved attention from survival and stocking in provincial surveys to growth and competition. Free-to-grow, free of competition, defined and implemented to various degrees, has become an important addition to current and anticipated performance standards.

In designing performance standards and in defining free-to-grow status many questions go unanswered as we have little information on mixed regeneration dynamics, competition dynamics and interactive growth of competitors and crop trees. Similarly, available data and our ability to forecast juvenile stand development are very poor. In most inventory sampling systems PSP's are rarely located in stands younger than 30 years. In that sense even the definition "Juvenile stand" is not adequately understood. What is the age range of a juvenile stand, 1-20 years? 15-30 years? Yet the need for wood supply projections and concerns about the reliability of computer simulations of juvenile and future growth have created a powerful mandate for monitoring and stand development modelling of juvenile mixed stands (Weetman 1987).

To fill the gap D. Brand, Forestry Canada (Brand and Weetman 1986; Brand 1988), has developed a biologically meaningful definition of the free-growing tree and a model for calculating and projecting free-to-grow status. Brand's free-to-grow model is based on the relative growth of the crop trees and competitors and is portable to any region of Canada where this type of definition is required. Brand (1988) also developed the system for assessment of regeneration and the software programs that provide summaries of free-growing projections, and application of GIS for mapping the total and free-growing stocking.

Forestry Canada, Northern Forestry Centre, has initiated a study aimed at defining the levels of aspen competition that affect lodgepole pine growth and at quantifying growth losses due to competition. The primary use for such information is in planning of tending treatments and forecasting growth and yield.

Less obvious but equally important are the other questions related to the role of aspen in the mixture, as a potential asset in the renewal process. Can aspen admixture be beneficial and function as a nurse crop? Aspen provides frost protection and shade not only in pine but also in aspen-spruce mixtures. Fast-released spruce is known to suffer from late frost and winter drying damage. Examples from fire-origin stands show that two intolerant species - pine and aspen - can grow together to rotation in mixed stands, but we do not know the composition of such initial mixed regeneration, or at what stage aspen admixtures become inhibitive to the growth of crop trees.

Silviculture of mixed stands

In Scandinavia and Central Europe the concept of a beneficial effect of species mixture on growth and stand

conditions has received much attention (Hagglund and Peterson 1985). The existence of positive effect on yield results from species mixture has been accepted, but the effect is not believed to exceed five percent of total yield (Frivold 1985).

It is recognized, however, that mixed stands have greater stability, greater resistance to the spread of root rots attacking conifers, and permanency of site productivity. Mixture of broadleaf species has positive effect on the nutrient cycling. On mixedwood sites in the boreal forest the number of years required for nutrient replacement of N, P, and K, following full-tree harvesting decreases with increasing hardwood component in the harvested stand (Table 2)(Gordon 1981). Pure spruce stands may increase soil acidification as shown for Norway spruce (eg. Kantor 1981) or white spruce in Canada (Brand et al. 1986).

Development of silviculture systems for regeneration purposes in the mixedwood zone of the Boreal forest has had more than a 60 year tradition. A 1966 publication on silviculture research by the Canada Department of Forestry, described a number of regeneration trials in aspen-spruce cover types spanning a period of 40 years. The studies investigated the value of various silviculture systems, ranging from clearcutting with hardwood residuals, clearcutting with residual spruce seed trees and uniform shelterwood cutting,for managing white spruce and aspen (Jarvis et al. 1966).

These studies provide a valuable source of information for current and future mixedwood silviculture treatments, such as the guidelines for release of white spruce from competition (Johnson 1986; Yang 1989) and white spruce understory release (Brace and Bella 1988).

The urgency of improved silvicultural knowledge for mixedwood management is great. As Armson (1988) writes "well tried silvicultural practices for the treatment of mixedwood stands are not available yet". The point is further argued by Rowe (1989) and Baskerville (1982) who suggest that the absence of understanding of biological dynamics in boreal forest ecosystems is a serious constraint to its management.

Two-stage silvicultural system for management of uneven-aged, mixed stands

Several silvicultural systems responsive to forest management objectives and site and stand conditions of mixedwood types will need to be developed. The two-stage silvicultural system consists of two harvesting and regeneration cycles (Figure 4) aimed at hardwood and softwood production from the same land base. The prerequisite of the system is controlled and prompt spruce regeneration after harvest of the parent mixedwood stand. This is achieved by applying the above discussed principles of white spruce natural regeneration. Seed tree retention, or other secured seed source, is mandatory in the first renewal cycle and may be extended into the second renewal cycle to enhance seed production from the now maturing released spruce trees. In the subsequent third cycle new seed trees would be selected from the trees of the maturing understory.

In an attempt to improve management of white spruce understory in fire origin hardwood and HS and SH stands, Brace and Bella (1988) developed a tending and harvesting scenario that realizes the growth and yield potential of existing white spruce understory. Harvest technology that provides adequate protection for white spruce understory during removal of aspen at the end of the first cycle is being vigorously tested (see L. Brace in this volume).

The two-stage silviculture system is well suited for adopting the management objective of a sustained yield policy for white spruce on the land base concerned. If needed for changing AAC goals, the system allows for

Table 2. Number of years for nutrient replacement following full-tree harvesting on mixedwood sites in the boreal forest (from Gordon 1981)

Mixedwood stand	N	P	K
25%S - 75%H	19	15	17
50%S - 50%H	20	16	19
75%S - 25%H	21	19	22

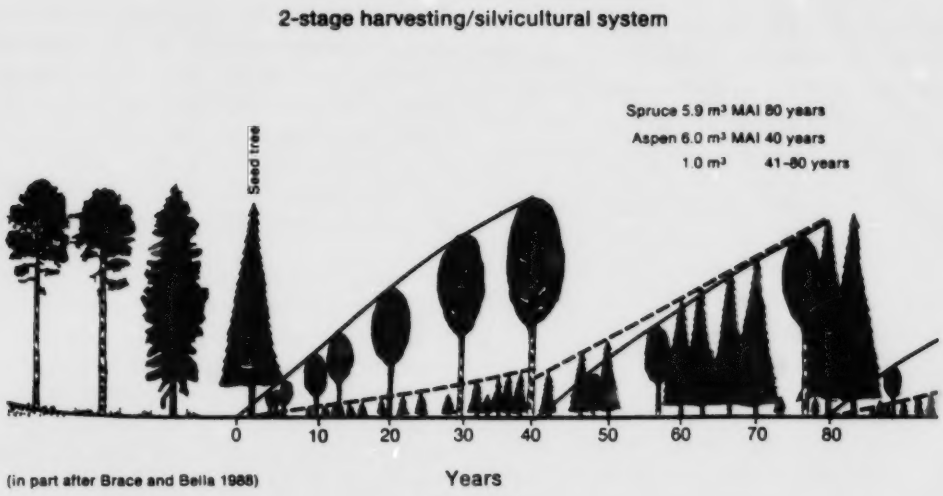

Figure 4

adjustment of the ratio of hardwoods and softwood production in the next rotation by promoting aspen establishment or by lowering protection of white spruce understory during harvest.

REGENERATION IN THE MIXEDWOODS IN THE FUTURE

Parabolic reminders

"Chunk the problems and blitz their solutions" (Management consultants)

Chunking means breaking things up into bits and pieces, fragmenting the problems. Though it works for industrial companies it may be counterproductive in forest management. The essential feature of forest management is that all steps and stages are interlinked in a long-term framework. In the past we have treated many solutions in isolation. We have put too much emphasis on survival and did not foresee competition problems and tending commitments. We were prepared to blitz competition problems with herbicides and now are poorly prepared for alternatives to herbicide use.

"Nature must be ridden not driven" (MacInnis & Rowland 1989, The Polar Passage)

It is not surprising that there is some disillusionment about the quality of regeneration on mixedwood sites. Perhaps we felt that we are powerful and that the forest ecosystem can be subdued.

Perhaps we expected too much for too little money and investment, and we overestimated our knowledge. We assigned renewal expenditures without knowing biological consequences. We must learn more about improving regeneration by adding to and enhancing the biological and silvical principles of the natural ecosystem.

Discipline the knowledge and investment loop

Regardless of the level of investment, regeneration success may fall short of objectives if it is not based on thorough knowledge of species silvics, responses to treatments, relationship to site and so on. Improved knowledge in all these areas can increase the cost-effectiveness of regeneration systems.

Securing appropriate conifer regeneration on mixedwood sites will require high initial levels of investment and continuous high levels of investment are unavoidable in ensuring that the conifer component in regenerated stands and softwood fibre yield will be brought to rotation age.

Figure 5 shows a generalized trend for the proportion of conifers in regeneration on mixedwood sites as a function of investment. At lower investment levels under more extensive regeneration practices we feel that the application of better knowledge can increase the conifer component. There is much information available on natural regeneration of white spruce that can be utilized. Knowledgeable modification of harvesting and site preparation practices and particularly integration of harvesting and silviculture operations can, at a minor additional cost, improve white spruce regeneration.

Better decision-making - Decision Support system for regeneration strategies on mixedwood sites

Selection of the most appropriate and best regeneration system requires substantial informational and technological input. Mixedwood issues are many, complex and interlinked. In many cases it is not possible for one individual to have all of the knowledge necessary to select the best system. This can be overcome by assembling a team of experts to organize, synthesize and access the information.

Rapidly emerging computer-assisted technologies (Decision Support Systems, Advisory Systems, Knowledge Based Systems, Expert Systems) have been used for strategic decision-making as well as for day-to-day tactical decisions in the manufacturing industry and are finding their way into forest management (Schmoldt and Martin 1986; Rauscher and Cooney 1986; Perala and Rauscher 1989; Pearce et al. 1990). These systems offer forest managers advantages in handling and compiling large amounts of fragmented knowledge and information, in integrating growth and other simulation models and in facilitating custom solutions to complex problems.

Silviculturists have tended to lag behind in the use of decision support technology, though some systems are being developed (Pearce et al. 1990). The complexity of decision-making in the renewal options for mixedwood stands offers a unique opportunity to benefit from "hands-on" support system tools.

In view of approaching FRDA renewals, Reed (1989) points out the need for a ranking system which assigns priorities objectively among a variety of regeneration and silvicultural options. Such a system requires syntheses of information on site productivity and growth predictions in regenerated stands that are unfortunately not at present readily available, but it emphasizes one of the roles to be filled by Decision Support Systems which incorporate rotation-length growth and yield prediction models.

Longer planning horizons need to be encouraged

There has been a tendency to focus on the results of individual regeneration treatments, rather than the entire renewal, silvicultural and management cycle. Regeneration is the cornerstone of forestry and the ripple, domino effect of deficient regeneration can be avoided by improving the quality of decisions on long-term effects of regeneration options.

Federal-Provincial agreements, which are a significant source of support for silvicultural activities in Canada, tend to constrain planning within the 5-year funding-renewal horizon. Regulatory requirements for renewal and corresponding silvicultural activities focus on survival and competition problems in the first 5-8 years of stand establishment. The acceptance of stand renewal as one phase of a silviculture and management system, and its integration with long-term growth and yield and economic projections will gradually force forest planning horizons to 40 or more years.

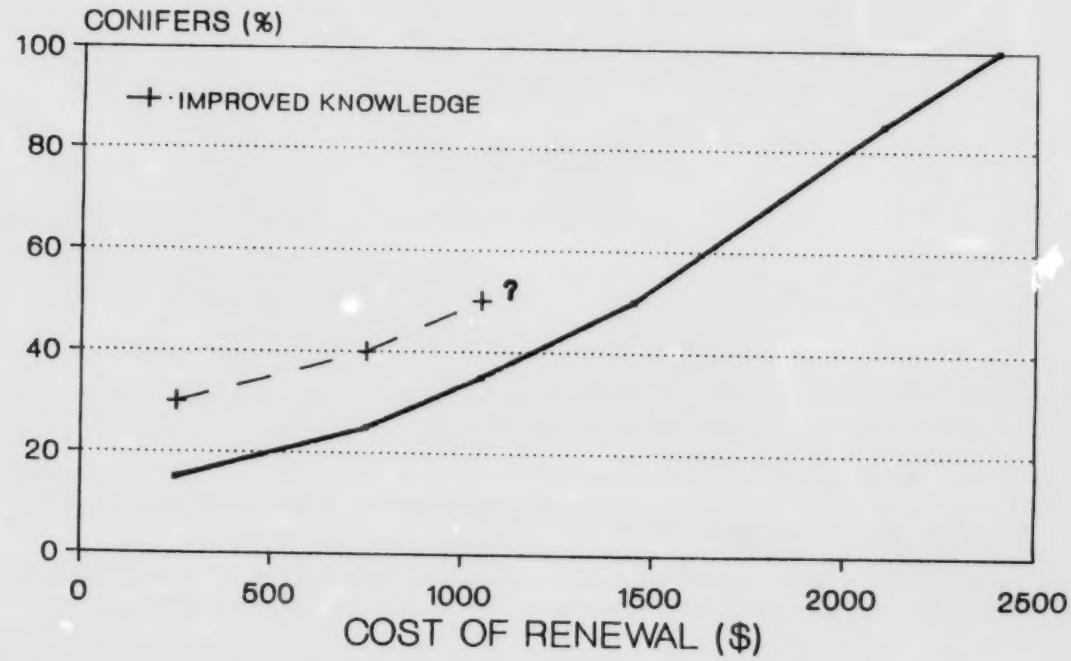

Figure 5

Regeneration options for extensive and intensive management in the mixedwoods

At the beginning of the paper we reflected on the performance of conifer regeneration established 15-20 years ago. Since that time knowledge of regeneration in the mixedwoods has improved; many things have been done well and worked well. We have learned from the work of Sutton, McMinn, and Revel. Older research on extensive silviculture systems in the mixedwoods initiated by Steneker, Lees and Waldron is now producing dividends and valuable inputs into silviculture options for the mixedwoods. Good examples of the returns possible from intensive management of white spruce on mixedwood sites are described by Willcocks (1980) and Arnup et al.(1988).

We expect that the following regeneration scenarios will be used in the mixedwoods:

Regeneration for hardwood production: aspen regeneration with a trend to short rotations

Regeneration for softwood production: coniferous plantations, monocultures with transition to mixed regeneration

Regeneration for hardwood and softwood production: mixed regeneration managed as even-aged, mixed stands at longer rotations, and in two-stage harvesting and silviculture systems.

We must develop and use the widest variety of regeneration options available for balancing extensive and intensive regeneration and silviculture systems, and for maintaining renewal capacity and species diversity in mixedwood ecosystems.

Wise use and selection of the best alternative can only occur when the forest manager can predict the consequences of various alternatives. This is only possible with a site classification framework upon which we can evaluate success or failure of regeneration, tree growth and successional changes.

Computer technology for planning and modelling regeneration and ecosystem response provides us with exceptional opportunities and tools for examining the consequences of decisions. However, we must remember that this technology is only of use when data from good field research or observations are available. Regeneration decisions must remain a strongly field oriented task.

Ecosystems, not short-term economics, should determine the correct regeneration and silviculture option. We must learn more about the complexities and dynamics of ecosystems, integrate regeneration objectives with ecological principles, and minimize the adverse consequences of our practices. The chain of understanding must start with the linkage of harvesting and silviculture and simultaneous design of harvesting, regeneration and silviculture plans.

The forests which we renew are the source of products other than wood. They also have potential to influence world-wide CO^2 and climate change. As a result, the actions of forest managers are becoming more complex and increasingly in the eyes of the public. We need to master a wide range of silviculture options and inform the public about the economic and ecological consequences of forest management alternatives. In mixedwoods ecosystems this demands that we bridge current information gaps and apply improved knoledge and understanding to both extensive and intensive management.

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HARVESTING IN THE MIXEDWOOD FOREST

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ABSTRACT

This paper discusses the preliminary results of a mixedwood harvesting study presently underway in central Alberta. The objectives of the study are to determine the costs, productivity, and effectiveness of using different types of harvesting equipment and systems to protect the white-spruce understorey while the mature aspen and conifer overstorey is harvested. Observations from studies completed to date indicate understorey damage can be reduced through careful planning, supervision, equipment selection, and operational practices.

INTRODUCTION

The Forest Engineering Research Institute of Canada (FERIC) has a mixedwood harvesting study underway in central Alberta. The objectives of the trial are to determine the costs, productivity, and effectiveness of using different types of harvesting equipment and systems to protect the white-spruce understorey while the mature aspen and conifer overstorey is harvested. FERIC is collecting data to determine equipment production and harvesting cost, and is observing equipment operation. Forestry Canada has established sample plots and is responsible for determining the extent of damage to the white-spruce understorey and predicting its longer-term survival.

The Canada/Alberta Forest Resource Development Agreement is supplying significant financial support for the field trial. Alberta Forestry, Lands and Wildlife is facilitating the harvesting trials and monitoring the results closely. Pelican Spruce Mills Ltd., Weldwood of Canada Limited, Blue Ridge Lumber (1981) Ltd., and Millar Western Industries Ltd. are harvesting the trial blocks.

This paper will present some preliminary results, observations, and conclusions based on the first two field trials. Unfortunately, wet weather has delayed logging the last area.

Protecting the white-spruce understorey in mixedwood stands has important implications for the forest industry in Alberta. First, the silvicultural costs of re-establishing a white-spruce stand would be significantly reduced because it would not be necessary to establish and tend new plantations. Second, in areas where the aspen and conifer harvesting rights have each been granted to different companies, attention given to protecting the white-spruce understorey while logging the mature stems can ensure a future crop for both companies.

The harvesting trials were designed to test whether under-storey damage can be reduced by:

- Following a designated skid trail pattern.
- Using different equipment.
- Increasing planning and on-site supervision.
- Incorporating special operating procedures.

FIELD TRIALS

Field trials have been completed at Drayton Valley and Hinton, and will be completed this fall at Blue Ridge. For each trial, three blocks of mixedwood timber are each logged according to a different set of specific logging prescriptions.

At the first trial at Drayton Valley, a tracked front-end loader feller-buncher, a faller, and four grapple skidders logged all three blocks. The first block was used as a control and was logged in the usual manner, i.e. without any special consideration given to the understorey. Aspen was mechanically felled and skidded, then the conifer was hand felled and skidded. The second and third blocks were felled and skidded using a designated skid-trail pattern. On both blocks, only the major trails and landings were located and flagged prior to harvesting, and the buncher operator located secondary trails. On the second block, the conifer

was hand felled after the aspen was mechanically felled and skidded, but on the third block the buncher felled the aspen and conifer at the same time.

On two blocks at the Hinton location, aspen and spruce trees were felled by excavator-type feller-bunchers and grapple skidded to roadside. Oversized conifers were hand felled. On the third block, aspen and spruce were harvested using a Swedish shortwood system that used one double-grip harvester and one forwarder.

No attention was given to protecting the understorey when the first block at Hinton was logged. The second block was felled and skidded following a designated skid-trail plan. All major trails were located and flagged prior to harvesting, and secondary trails were located and flagged during logging. In addition, a number of tall aspen stumps were left to act as rub posts at turning points, all bunches were limbed and topped on the skid trail prior to skidding, and a company supervisor was always on site during harvesting.

The third block at Hinton was logged at the discretion of the machine operators. The Swedish harvester felled the aspen and spruce trees, then delimbed and cut the stems into logs. The forwarder picked up the logs and carried them to roadside.

STUDY RESULTS AND DISCUSSION

Results of the study to date suggest that the harvesting pattern, equipment operation during falling and extraction phases, work practices, and supervision and planning are the main factors to address if damage to the white-spruce understorey is to be minimized.

Harvesting Pattern

Conventional harvesting operations damaged the understorey because skidders damaged residuals as they travelled a new route to the landing on each cycle. In contrast, the designated skid-trail pattern concentrated understorey damage to specific trails and left islands of undamaged understorey between the trails.

Falling Phase

Preliminary results indicate that although feller-buncher production in the designated skid-trail areas may have decreased because of increased manoeuvring around merchantable conifer and dense patches of understorey, bunch size appeared to be larger because limited areas were available for placing bunches. As a result, skidder productivity may have increased.

The type of mechanical felling machine, its carrier size, and the type of felling head, contributed to understorey damage. Both of the bunchers that FERIC monitored avoided damaging the understorey by carrying the severed stem vertically and placing it along the skid trail. More falling damage occurred with the Swedish harvester because it could only assist the placement of the felled tree and the stem dragged against the understorey as it was pulled through the processor.

The front-end loader-type buncher was the narrowest of the machines used in the trial. However, it had to position itself in front of each tree and residuals were damaged during turning. The excavator-type buncher could use its boom to reach 3-4 m to cut trees and did not have to reposition the carrier at each tree. However, in this case the residuals were knocked over by the head and the counterweight as the machine swung around to cut or bunch. The Swedish harvester had a two-piece 10-m long boom that could carry the head above the understorey while it swung around to another stem.

The larger the felling head, the more difficult it was for the carrier to position the head around a stem without damaging adjacent understorey. The Swedish harvester head was the smallest and had the most flexibility in positioning. Damage to dense pockets of conifer understorey also occurred when individual, sub-merchantable, non-merchantable, small-diameter, mature stems were felled. This was caused by the carrier or the head knocking over residuals while getting to the stem.

Extraction Phase

Preliminary results of the skidding studies indicate the designated skid-trail system appeared to lengthen skidding distances because the skidders had to take a circuitous route to the landing, rather than a shorter more direct route. However, overall skidding time along the designated skid trails did not appear to increase because the trails became faster with use, skidder operators did not have to spend time looking for the best skidding route, trails that would be seldom used did not have to be built at all, and time was not spent repairing hoses or lights that would otherwise have been knocked off when the skidder was travelling through dense patches of residuals. The larger size of the bunches along designated skid trails also assisted in maintaining productivity.

Understorey damage during the extraction phase was related to the method of falling and extraction, and to the size of equipment. Hand-felled timber required that the skidder travel over a wide area to collect a bunch of stems and then align the stems in the direction of skidding. The

designated skid-trail pattern minimized the areas traversed because the bunches were located only on or alongside the trails. The tracked front-end loader-type buncher created a trail that was just wide enough for the skidders but too narrow for the larger conifer bunches. The excavator bunchers created wider roads that could accommodate the skidders and the bunches. The forwarder appeared to cause less disturbance than the skidders because it was the same width as the harvester and logs were carried to roadside. Residual damage also appeared to be related to the number of times the skidder had to re-enter the block, and understorey damage appeared to increase when the skidders had to make a second pass to collect conifer stems after the aspen had been skidded. It appeared that less residual damage occurred when the skidder collected both species during the same entry. Damage to the residuals beside the skid trail was reduced when the bunches were aligned to the skidding direction. This reduced the need to swing the bunch around tight corners at breakout, during skidding, and when aligning the turn with the landing.

Damage to the understorey was reduced at breakout points and along the trail when both aspen and conifer bunches were delimbed prior to skidding. High stumps left beside the trail as rub posts were also effective in deflecting stems around trail-side understorey.

Supervision

From the studies completed to date, the effectiveness of on-site supervision in reducing understorey damage appeared to be related to the complexity of the plan, the experience of the crew, and the willingness of the supervisor to be on site and to supervise. The simpler the plan, the less supervision was required. Plans that required laying bunches in herringbone patterns at specific angles beside the trail, skidding along designated paths, and limbing bunches in the bush were only carried out properly when the crew understood why the understorey was being saved, if the crew did not think it would lose money, and if a supervisor was on site to enforce the practices. The on-site supervisor guided the crew regarding which residuals needed protecting and which residuals it was practical to protect. For example, the supervisor ensured that areas where understorey was destroyed were used for landings or trails and, that one residual was not saved while two others were damaged.

To date, the study has revealed that when the crew members understood what the trials were trying to achieve and why, they made a conscientious effort to reduce residual damage. They also suggested further operational changes that helped reduce damage to the residuals.

Several of the operating practices used in the study to reduce understorey damage would require acceptance by the regulatory agencies. The use of rub posts required leaving stumps up to 1.5 m high. The Swedish harvester and limbing in the bush left limbs and tops concentrated on the trails where it could be difficult to burn or spread them out, and the recovery of a few sub- or non-merchantable stems in the middle of dense understorey caused more residuals to be destroyed.

Planning

Results of the trials to date suggest that planning, in conjunction with effective implementation, plays a key role in protecting the white-spruce understorey. In the study areas where more intensive planning and layout was carried out, the crews spent less time deciding where trails or landings should go, and less time building roads, trails, and landings. In addition, laying out all trails and landings as early in the operation as possible ensured there were alternative areas to work in when equipment had to be relocated, and that landings were located in areas of reduced understorey, even if this meant increased skidding distances. Planning is also the phase where the costs of harvesting the mature stems must be determined and the increased harvesting costs associated with understorey protection must be balanced with the long-term benefits. For example, understorey protection reduces the need to plant, it helps control the competing vegetation, and it provides valuable habitat for wildlife.

PRELIMINARY CONCLUSIONS

Damage to the white-spruce understorey in mixedwood stands can be reduced through careful planning, equipment selection, supervision, and the use of special operating techniques.

Careful planning involves:

- Matching equipment to stand conditions.
- Incorporating work practices that are most effective in relation to the amount of supervision available.
- Balancing harvesting costs with the benefits achieved.

Those individuals responsible for layout need to consider understorey protection as early in the planning process as possible. The plan should:

- Recommend the use of the smallest possible mechanical felling equipment possible to fall the stand in one pass, so that a tree is positioned when it is felled or placed in bunches along the skid trail, and a second entry into the stand is avoided.

- Propose a pattern of skid trails that do not have sharp corners and are aligned to the landing, and have trails located and flagged before harvesting starts.
- Locate landings in areas of minimal understorey and keep landings as small as possible.

Even the best plan will not reduce understorey damage unless its implementation is supervised. Supervisors must explain to the crew what the objective of the plan is and how the plan will be carried out. A supervisor must be on site to ensure that the crew understands and is achieving the desired result, and to modify the plan as required. Supervision of the mixedwood logging areas by regulatory agencies requires an acceptance of practices that may not be currently allowed in conventional logging, i.e. higher stumps left as rub posts, more debris in the block from limbing and topping, and the leaving of standing non- or sub-merchantable trees.

Protection of the white-spruce understorey can only occur with the co-operation and active involvement of all individuals: the crew, the supervisors, and the regulatory agencies.

PEST MANAGEMENT TOOLS FOR MANAGING THE BOREAL MIXEDWOOD FOREST

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INTRODUCTION

Mixedwood forest pests create problems for the forest manager. Pest management attempts to solve these problems and improve the productivity of the managed forest over its unmanaged counterpart. In the mixedwood forest, however, special constraints are imposed on these solutions because of geographic, demographic and economic considerations peculiar to this region. The vastness of the area to be managed, the length of rotation ages and the values of products derived from these forests to be used in distant markets dictate that only extremely low-intensity management options are economically justifiable at present.

Management is the process by which one controls or directs a system to achieve some goal. This implies that the manager has some knowledge of how the system functions and how it reacts to any treatments prescribed. The management alternative selected in any situation is equally dependent on the management objective and the knowledge base used to arrive at the decision. Mixed wood forest management decisions are likely to present the manager with a large array of options because of the complexity of the stands being managed. Our contribution to this symposium is to provide a sketch of the information available which may be used to manage pests of forest stands of the mixedwood section of the Canadian boreal forest. To the extent possible, examples from northeastern British Columbia will be used.

The trans-continental boreal forest is characterized by the presence of white and black spruces with balsam fir and jack pine of eastern and central forests giving way to lodgepole pine and subalpine fir in the west (Rowe 1972). Mixed with the coniferous species are the birches and trembling aspen. In the Mixedwood section of this forest (Rowe's B.18a, or boreal white and black spruce in terms of biogeoclimatic terms) the characteristic forest association of upland, well-drained sites is a mixture of trembling aspen, balsam poplar, and white birch. White spruce eventually predominates on these sites as the stands age. The prominence of aspen in this region is due to its remarkable ability to regenerate following disturbance. On drier sites, jack pine or lodgepole pine enter the forest association and is dependent on fire for stand regeneration (Rowe 1972). Most commercial forest operations deal with forests of the well drained and drier sites. Tamarack and black spruce, which are found on the wetter and more northern sites, are also ecologically important in the mixedwood forest section.

Associated with each tree species is a suite of insects and micro-organisms which feed on different tree tissues. Similarly any forest stand is the site in which a variety of plant and animal populations spend all or part of their existence. Whether any one of these organisms is labelled a pest or not depends on the human demand for, and nature of products derived from the stand. There are examples where an organism is considered beneficial in one context and a pest in another. The changing fortunes (from a forestry perspective) of aspen in the mixedwood forest has elevated some insects and diseases previously regarded as benign or not worthy of control to "prime pest status." Indeed, aspen itself is viewed with this ambivalence, even today, depending on whether you are persuaded that softwoods or hardwoods are the raison d'etre of mixedwood forestry. Before designating a species a pest, it is essential that the ecological characteristics of the species and its significance to the management objective for the stand in which it is found are fully appreciated.

Treatments of pest management concerns at previous symposia provided descriptions of pests, their life cycles

and insecticidal or silvicultural control options (Davidson and Prentice, 1968; Hinds, 1985; and Jones et al. 1985). The major focus of these works was on pests of the hardwood component. Important information regarding the effects of pests on stand development was also presented in these reports. The need to integrate this information for use in the mixedwood forest management prescriptions was commented on by Volney (1988a). The major conclusion repeated in all these papers is that insect and disease losses can be minimized if healthy, fully stocked stands, free of disturbances are maintained. The processes underlying this suggest that natural defenses of trees are lowered during disturbance (from wind, frost, drought, mechanical, sun scald, or pest damage) making the trees susceptible to secondary pest attack, growth loss, and mortality. Presumably the process of opening up the stand further weakens trees and contributes to the demise of aspen stands. These conclusions rely on observational studies which have not been rigorously tested by experiment. Further, many of the relationships described have not been quantified.

Despite the shortcomings of the information, managers still have to make decisions. Yet there is a large body of information which needs to be analyzed, interpreted, its utility evaluated and the pertinent conclusions used in improving the knowledge on which forest pest management decisions are made. A tool, which will have a major impact on the way pests are managed and one which is in need of development, is a means to make pest related information easily accessible to managers.

INFORMATION ON PEST MANAGEMENT:
The long and short of it

Before any attempt is made to manage pests it is important that the identities of the organism capable of causing damage to a stand are known. Considerable effort has been expended to compile this information. Over the past 53 years, the personnel of the Forest Insect and Disease Survey (F.I.D.S.) of Forestry Canada and their cooperators have put together a fairly complete list of the organisms which feed on trees found in mixedwood forests. Beginning in the early 1950's this unit has compiled some 6000 records from the Peace River Area of British Columbia. More than half of these records are of species that are not considered pests. Nevertheless these records are important in permitting specialists to identify recent introductions, and in recognizing the potential for secondary pest problems as new forest management techniques are introduced. These records also include listings of beneficial organisms such as predators and parasites.

Approximately 1/5 of the 6000 records were diseases and the rest dealt with insects. The most common of these were foliar pathogens (10 species), stem or branch rusts (5 species), 1 cone rust, 3 canker fungi, and 4 major decay fungi. Among the insect records there were 21 defoliators (15 on conifers), 4 bark beetles, 2 wood borers, 2 terminal weevils, 5 gall midges or aphids, 5 cone insects and 6 beneficial insects. This list is not long. With a little help any forestry practitioner could become acquainted with the signs and symptoms used in the field-diagnosis of these pests. More importantly, the trained practitioner can then become part of pest detection surveys.

There are a number of field guides and manuals available to help in the identification of pests. A series of these have recently been produced by the Northern Forestry Centre. These deal with the diagnosis of damage to trees in the mixedwood forest including: air pollutants and natural stress agents (Malhotra and Blauel 1980), diseases (Hiratsuka 1987) and insects (Ives and Wong 1988). These manuals treat far more species than would ordinarily be encountered as pests but they serve the purpose of distinguishing pests from benign organisms. These manuals are excellent for use as self-help guides in pest identification. Forest pest leaflets on a wide range of pests are also available from the Pacific Forestry Centre and the Northern Forestry Centre. Both these centres provide an identification service for insect and disease samples originating from forestry concerns in their respective regions. Another set of tools for pest management then, are the collection records for the region and the identification manuals produced largely as a result of this experience.

Besides the identification and determination of pest status of these agents, the F.I.D.S. records serve a second purpose. Because the record spans several years (35-40 years in this area and 53 years in other areas of the mixedwood forest) it is possible to develop spatial and temporal descriptions of outbreak patterns of pests we should be concerned about.

The outbreak patterns for the important insect pests of the aspen component of the mixedwood forest are presented in Figure 1. The most important of these has been the forest tent caterpillar which caused damage during four different intervals in the past 40 years in northeastern British Columbia. Details of the areas affected are presented in the F.I.D.S. annual reports (eg. Wood and Van Sickle 1989) and the Pacific Forestry Centre F.I.D.S. poster presentation at this session. Conditions in other parts of the mixedwood section are reported in the annual reports of the adjacent region (eg. Emond and Cerezke 1989). National summaries are also prepared annually (eg. Moody 1988). Large aspen tortrix outbreaks are more

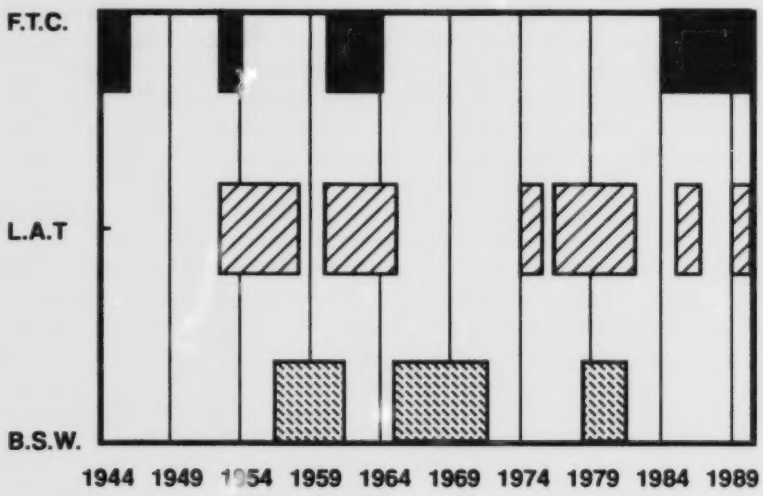

FIGURE 1: Outbreak histories for the major aspen defoiators of northeastern British Columbia. A) Forest Tent Caterpillar, B) Large Aspen Tortrix, C) Bruce Spanworm

frequent but of shorter duration, occurring 8 times in the past 40 years. Bruce spanworm outbreaks have occurred 3 times in the past. All stands are not affected by every outbreak and no stand is subject to every outbreak. Thus the distribution of outbreaks within an area is very important in evaluating the significance of each of these outbreaks on individual stand development.

Fewer outbreaks have occurred on the conifer component. Outbreaks of the spruce budworm have been reported mostly north of the mixedwood section of British Columbia. Damage caused by the two-year cycle budworm to mature spruce stands in the three outbreak periods of 1950, 1954-57, and 1962-64 was negligible. Similar comments can be made of damage caused by the larch sawfly in the two outbreak periods in 1962-68 and 1975-77. Problems might be anticipated with the spruce beetle. This species has attacked trees where populations have built up in nearby weakened trees, recently killed trees, or decked logs. Monochamus wood borers have also caused damage to decked logs and salvaged fire-killed logs.

Diseases are probably under-represented in annual surveys because of their characteristic slow spread in stands. Of major concern are the rots. Trunk rot in aspen, red ring rot, brown cubical rot and tomentosus rot in conifers are common. Damage to older trees, including top-kill and radial growth reduction, has been caused by broom rusts of fir and spruce. Stem and gall rusts, though present, have not been major problems in older lodgepole pine stands. Other diseases that are local and patchy in occurrence include spruce cone rust, needle casts, needle rusts, ink spots and shoot blights. Animal damage, damage from frost, and snow breakage have also been reported in the Peace River area of British Columbia.

Perhaps the most important value of this historical information to pest management is that it provides a means of developing some understanding of pest epidemiology and making long-term forecasts. For example, the jack pine budworm outbreaks in forests of Saskatchewan and Manitoba were recently analyzed and long-term and short-term predictors of outbreak occurrence developed (Volney 1988b). The outbreak information used in these analyses was largely collected by the Forest Insect and Disease Survey and its forbearers. Similar analyses are possible with the other major defoliators of the mixedwood section to develop forecasts on the occurrence and extent of damage.

These predictors can be used by forestry concerns to formulate policies and plans for the inevitable outbreaks occurring in the region. If the effects of these pests on the forest resource is to be minimized, this policy will most likely include statements on the priority of stands to be harvested. These priorities would be developed from a consideration the probable losses from pests in addition to all the other considerations normally used in developing harvesting schedules.

Knowing the long-term and regional expectations of damage does not provide the manager with the detailed information required to evaluate the hazard for specific stands. Hazard rating stands in the mixedwood forest is in its infancy. However, several components of this tool have been developed for a variety of pests. For example, pheromone trapping techniques are being calibrated to permit the prediction of spruce budworm defoliation in spruce stands (Sanders 1988). The attractants that would permit monitoring all the major aspen defoliators in the mixedwood forest of northeastern British Columbia have been at least partially identified. Synthetic pheromone preparations for the forest tent caterpillar are being tested, for detection purposes, having been identified in 1980 by Chisholm et al. (1980). A pheromone component of the large aspen tortrix has been reported (Weatherston et al. 1976). A sex attractant for the Bruce spanworm moth has been characterized (Underhill et al. 1987). Attractants for the jack pine budworm, a pest of eastern forests of the mixedwood section, have also been field tested (Butterworth and Silk 1989). These tools could be developed in concert with the traditional detection surveys to provide improved site-specific and short-term forecasts of population increases and potential for damage to the stand.

Less information is available on the effects of pests in reducing stand yields. Nevertheless, there are means of predicting the impact of pests on stand productivity from present and future outbreaks. An example of the effect of a forest tent caterpillar outbreak on the development of young aspen stands was presented at the last mixedwood symposium (Volney 1988a). Based on the modeling efforts of Mattson and Addy (1975) the net effect of one outbreak was a 25% reduction in the accumulated stem wood biomass and a permanent reduction of the capacity of the stand to realize its maximum yield. Predictions of pest impacts can be adjusted for local conditions. The impact information now being acquired by F.I.D.S. personnel in this region together with other forest inventory data would ultimately permit predictions of this sort to be made. The important point is that repeated outbreaks have considerable impact on the productivity of stands.

What can be done about forecasts of unacceptably high pest populations? Perhaps the single most effective treatment tool available to the forest manager is modification of harvest schedules to harvest high-risk stands before they sustain unacceptable levels of pest damage. This technique has the appeal that there is no, or very little, increased cost in its application and there is little increased environmental risk in its implementation. The disadvantage is if the proportion of stands in the high-risk category is large, it will be impossible to harvest all stands requiring treatment without seriously affecting future timber supplies. When this occurs, other techniques have to be resorted to. Direct control of defoliators has been practiced in Canada for several years. Presently, the favored control technique for the forest tent caterpillar on large areas is to aerially apply a biological insecticide, Bacillus thuringiensis (or B.t.). Although not specifically registered for the large aspen tortrix, this insecticide is known to be effective in reducing damage from the large aspen tortrix (Holsten and Hard 1985). (As the registration status of individual preparations change it is best to determine which materials are registered for specific pests on each host for a particular use by checking with the Pesticides Directorate of Agriculture Canada and the provincial agencies which regulate pesticide use in the jurisdiction concerned.)

In some situations a do-nothing option may be valid. More than a dozen parasites of large aspen tortrix along with disease and weather usually cause collapse within three years. Because the larvae feed early in the spring, the trees refoliate in the same year usually with little tree mortality. The impact on growth and risk of attack from secondary pests may be sufficiently low to be acceptable at current levels of management. Impacts on aesthetics or public concerns may be greater.

Silvicultural treatments to mitigate pest conditions in mixedwood stands have not been developed. Some silvicultural treatments may exacerbate pest effects. There is considerable experience to suggest that heavy thinning of aspen stands to release spruce may not achieve the desired result. Young white spruce trees are extremely susceptible to attack by the white pine weevil, so much so that it is called the spruce weevil in this western province. The result of opening up stands prematurely can, therefore, be quite devastating on understory white spruce. This could be a potential problem in the Peace River region as forest management intensifies. Diseases which are now benign in the region, such as septoria canker, may become a problem with the introduction of hybrid and exotic poplars (Davidson and Prentice 1968).

PEST MANAGEMENT AND EXPERT SYSTEMS

A self-improving solution?

Pests create a bewildering array of concerns for the forest manager who often feels ill-equipped to make decisions regarding pest management. Further, there is often a sense that the information available is incomplete or unavailable, despite the enormous amount of effort expended by specialists in the past. To further exacerbate the manager's predicament, pest management specialists may not be available to provide the individual attention required to

satisfactorily design and implement pest management protocols for the land base being managed. One tool developed to assist resource managers is the pest management system.

Forest pest management should be an integral part of integrated resource management. As such, the decisions to acquire information about pest conditions, to treat stands and to evaluate treatments have to be compared to the competing opportunities for the funds required to perform all activities of the management agency. A crucial concern in this regard is how the information required to manage pests is to be acquired and utilized. Pest management systems perform these functions. A typical system might consist of procedures to: monitor pest conditions in individual stands, forecast the likelihood of damage from the pest conditions reports, decide on a course of action, and to monitor and evaluate the results of the prescribed action. These procedures are based on an understanding of the reciprocal interactions among pest populations dynamics, stand dynamics, and treatment effects. The response of the pest populations and stand productivity to the various treatment options are evaluated using econometric tools to obtain benefit/cost ratios which can be used to select among the options available to the manager. Depending on the complexity of the situation involved, this system may be automated to varying degrees using computer-based models in addition to other decision support systems used to collect, process, and display information required to make decisions in forest management.

Despite the development of decision support systems and pest management systems for several major forest pests in other regions of North America, several of the tools were not applied (Coulson et al. 1989). One of the major causes for this was the difficulty of handling incomplete information. This difficulty is compounded by the scarcity of specialists to assess the utility of opinions and evaluate the consequences of using "best guesses" which experts often are forced to use when faced with inadequate information. Systems are now being developed to overcome these deficiencies (Coulson et al. 1989).

Known as knowledge-based systems, or more commonly, "expert systems", these tools attempt to simulate the reasoning used by experts in dealing with the management of complex enterprises. An expert system contains a "knowledge base" in which all knowledge available on a subject is coded in a fashion that makes it accessible to an "inference engine." This inference engine processes the information, updates the knowledge base with current information and produces a recommendation for the manager's scrutiny. The manager has the option of obtaining statements on how the system arrived at a particular recommendation. A characteristic of expert systems is that the information fed back to the system as a result of action can be used to modify the knowledge base. Thus the experience gained from implementing any action on the forest is immediately incorporated to improve the knowledge-base. This is analogous to learning from experience, and is critical to improving our understanding of the system being managed.

Expert systems designed for forest pest management will probably have several peripheral systems to assist in automating the decision making process as well as managing and acquiring the data sets. In situations where many individual stands are being managed, a geographic information system would become an important component of the expert system. Other utilities would include connection management systems for managing information flow among several distributed work sites, data base management systems for data management, and various output devices to display results.

A final feature of these systems is that they can be configured to address the questions asked by managers at several levels of the management hierarchy. Thus the district forester, the regional resource management officer, and the chief forester of an agency can utilize the same information to make decisions at different administrative levels.

The costs, constraints, and benefits involved in expert system development for forest pest management in conditions such as those of the northern mixedwood forest were discussed recently (Volney 1989). Expert systems of this sort are expected to take six to eight person years to develop provided that the necessary experts can be assembled and persuaded to participate. In addition to the fuller utilization of available information in making decisions, expert systems offer an opportunity to overcome some of the training and technology transfer problems the older systems encountered in their implementation. Of equal importance, they will not replace human experts but will serve to assist them in focusing on the more difficult pest management problems.

CONCLUSIONS

The tools required to manage pests of the mixedwood forests are the ability to: identify pests, predict the threat pests present to achieving forest management goals, evaluate the need for treatment, select the best treatment warranted; and evaluate the results of treatments. How good these tools are depends on the skill of the manager in applying what is available. All tools (be they pest identification, pest conditions assessment, predictors of spatial and temporal characteristics of outbreaks, hazard rating methods, or impact models) need improvement. The real challenge is to improve them in a manner which will result in the greatest improvement of management results for the effort expended. A means of improving our skills of managing pests, the information about managing pests, and of improving our understanding of the deficiencies of the knowledge-base may be provided by expert systems.

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INTEGRATED USE IN MIXEDWOOD FORESTS – A CHALLENGE

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ABSTRACT

The mixedwood forest in northern Canada and the aspen ecosystem in the western U.S. have many similar values. Both types are excellent for multiple- or integrated-uses. They have a moderate but increasing value for wood products; they furnish excellent habitat for many wildlife species; they have abundant forage for livestock and big game; they provide superb watershed protection, especially on steep mountain catchments; and, they have aesthetic appeal, particularly on mountainous landscapes in a mosaic with meadows, pure stands of conifers, and pure stands of aspen. In the United States no single value dominates and controls ecosystem management. Integrated management is practiced. Active management is necessary to retain aspen on most sites because it is seral and will give way to more tolerant conifers if protected long enough from catastrophic events, especially fire. Management of the aspen and the mixedwood systems for their multiple values is preferred. Good silviculture and multiple-use management are quite compatible. The dynamic and resilient nature of these ecosystems facilitates management.

SIMILARITIES AND DIFFERENCES

The mixedwood section of Canada has many similarities with the aspen type of the western United States, with which I am familiar. These similarities dominate the following discussion on integrated use. However, there are major differences between the aspen type in the western U.S. and your mixedwood complex. These differences, both socioeconomic and ecologic, must be kept in mind if application of the U.S. multiple-use experience is to be successfully applied to your vast mixedwood system.

SOME SIMILARITIES

- Aspen originates after some major disturbance, usually fire, and is successional to conifers on most sites.
- Abundant understory vegetation grows under aspen; sparse understory under conifers.
- Much of the land in the mixedwood and in the montane aspen is remote and relatively inaccessible. Construction of expensive roads is necessary to put a moderately valued forest under management for wood products.
- Wild ungulates are an important part of the ecosystem.
- Relatively low or no value of the aspen for wood fiber in many areas; but there is a rapidly increasing interest in its utilization.
- Most of these forested lands are publicly owned and managed.

SOME DIFFERENCES

- Succession from aspen to high-value white spruce in Canada but succession to valueless sub-alpine fir on many sites in the U.S.
- A primary value and use of the aspen type in the western U.S. is livestock grazing; much less so in the mixedwoods of Canada.
- Mountainous terrain throughout much of the aspen type in the western U.S.
- There is a greater emphasis on recreation and aesthetic values in the western U.S. aspen ecosystem because of the mountainous terrain and its proximity to large population centers.

- A smaller percentage of people in western U.S. communities within the aspen area are dependent upon forest industries for their livelihood.

- The U.S. aspen ecosystem, being further south, mountainous, and with a broad array of sites, has a greater number of tree and understory plant species than do equally large areas of Canada's mixedwoods.

- Public ownership and management of forests is much different in our two countries. The U.S. does not have corporate long-term leases for timber management. Each timber sale is bid as a separate entity.

THE CHALLENGE

The challenge to integrated management in the mixedwood type of Canada will require some of the same changes in thinking and attitudes on the part of silviculturists and timber managers as was required in recent decades in the United States. On large areas of forested public lands in the U.S., the value of wood products has, with some reluctance, been given a secondary or tertiary position behind other wildland uses. The silviculturist has had to become a team player alongside wildlife, range, and watershed managers, recreation specialists, landscape architects, and archaeologists. No longer is the traditional forester "in charge"; no longer do wood product values and the silvicultural system control management. For better or worse, the spotted owl seems to hold equal place with timber from coastal Douglas-fir, and aesthetics and recreation with flakeboard from Colorado aspen. I'm not sure that all of this is "good"; it has had economic impacts. But it has re-focused the vision of many "timber beasts" who saw the forest only as a wood factory.

Today, on public lands, the best leaders are those who are able to integrate the multiple values and uses of the wildlands in their charge. This is the first facet of your challenge for integrated use in the mixedwood—to refocus as necessary the vision and emphasis of forest land managers. The forest is more than trees. A second facet of the challenge is one of education and salesmanship. Managers of wildlands, both public and private, must have public support for major policy decisions and management actions. The managers who have a thorough understanding of all the values of the mixedwood forest must transmit that knowledge to their colleagues, employers, constituents and the public. Then, when integrated use decisions or proposals are made, they will continue to be supported as professional and responsible resource managers. Special interest groups must be considered. On public lands in particular, public involvement becomes part of the policy and decision making process. On private lands, the manager must educate the rest of the corporate structure. In effect, the manager becomes a salesman for balanced (integrated) resource management on forested land. Resource values, both present and future, must be considered. This is the second facet—to educate and sell the integrated management program within the organization and to the public.

The third facet to this challenge is one of prediction. We must look into the crystal ball and accurately determine what the market and society is going to demand from this mixedwood system in the next century.

If we assume that transportation will continue to be relatively inexpensive and that much of the world will continue its present standard of living, then we can predict that the economy of this mixedwood area will grow and prosper during the next 30 to 70 years. If the above assumptions do not hold, the mixedwood might again become as isolated from the food producing and heavily populated parts of the world as it was 30 to 70 years ago. On the other hand, the global warming that has been predicted by some may make this area the breadbasket of North America within a century.

I prefer to be optimistic; that transportation will remain cheap, and that a significant portion of the world's population will enjoy a high standard of living with considerable leisure time activities. If my prediction holds, then the mixedwood system of Canada will continue to grow in importance as a supplier of fiber (cellulose), outdoor recreation, and, as a spin-off from the latter, red meat and fish.

I further predict that advanced wood products technology is going to make maximum cellulose production from the mixedwoods more important than management for any given tree species. Optimum habitat for a diversity of wildlife, especially large ungulates, will be equally considered with good production in silvicultural prescriptions. Aesthetics and watershed values will grow in importance as well.

If wood production, wildlife production, recreation, aesthetics, and watershed (especially as it pertains to aquatic habitats) hold equal importance for your future wildland managers, then they will be facing the same challenges as the present managers of aspen lands in the Lake States and western U.S. It is based upon these predictions that I make my suggestions for integrated multiple use management of the mixedwood.

RECOMMENDATIONS

About 5 years ago I wrote a chapter entitled "Management for Esthetics and Recreation, Forage, Water, and Wildlife" for the book, "Aspen: Ecology and Management in the Western United States" (DeByle and Winokur 1985). Many of the recommendations made in that chapter apply, with some modification, to the Canadian mixedwoods.

Integrated use comes with tradeoffs and costs. Hopefully, any lost timber production and lost efficiency in harvesting will be more than offset by enhancement of other values and increased returns from other resources in this mixedwood system.

RECREATION AND AESTHETICS

Where a satisfactory road network is present, particularly on hilly or mountainous terrain, a mixed forest of hardwoods and conifers provides intangible returns in the form of recreation and aesthetics. Management activities in this setting in the long run can be used to enhance rather than detract from aesthetic values.

Clear-cuts may be used to create variety in dense and continuous stands. The clear-cuts should be small, irregularly shaped, and fit into the landscape. Minimize the impacted area that can be seen from any given point on the clear-cut. Make sure that all operations appear neat and organized with no unsightly debris and litter. Properly treat skid trails and landings as the operation progresses. Roads should fit into the landscape. Don't harvest adjacent to a clear-cut until it has had sufficient time to regain a forested appearance. Provide for permanent scenic vistas and keep them open. Provide for a diversity in forest types, species mixes, and size classes on the landscape (Perala 1977).

Aspen forests are great for dispersed recreation. Aspen also is good cover on ski areas. But this species does not tolerate concentrated human activity, as in developed campgrounds (Hinds 1976). Place your campgrounds in conifers or at least in a mix of conifers and hardwoods.

WATERSHED VALUES

The watershed manager is concerned with water quality and yields. If erosion from the forest site reaches the stream, it becomes sediment, which drastically reduces water quality. The undisturbed mixedwood forest provides excellent soil protection; overland flow and erosion are minimal. However, clear-cut harvesting, heavy grazing, road and firebreak construction, and fire all have the potential of baring sufficient mineral soil to permit accelerated erosion. Fortunately, in much of the mixedwood, the soil bared through these disturbances again is quickly protected within a year or two with a cover of aspen, shrubs, and herbaceous plants. Nevertheless, the manger should strive to maintain at least 65% soil cover and minimal sized bare soil openings on erosion susceptible sites (Marston 1951; Meeuwig 1970). The vegetation in and adjacent to stream channels should not be disturbed. And, roads, skid trails, landings, and similar areas should be treated so they will not erode.

Timber harvesting will increase water yields. In the western U.S., clear-cuts in aspen yield 10 to 15 cm more water than the uncut forest (Johnston et al. 1969). Regrowth of aspen suckers is rapid; and water consumption by the regenerating forest should negate the increased yields within a decade after harvest. Conifers use more water than aspen. They also reoccupy a site more slowly after harvesting. Hence, clear-cutting a conifer stand will have a greater effect on water yields for a longer period of time than will clear-cutting an aspen stand.

FORAGE

The aspen type in the western U.S. commonly produces 1,100 to 2,250 kg/ha of undergrowth each year (Houston 1954). Much of this production is a palatable and highly nutritious forage that is heavily utilized by both wild and domestic ungulates. In stark contrast, conifers on similar sites yield only a fifth as much forage. As conifers invade and take over a site, forage production rapidly decreases.

Clear-cutting or fire in the aspen or mixed aspen-conifer forest results in a significant increase in undergrowth production that is even more palatable and attractive to ungulates (Bartos and Mueggler 1982; Brown and DeByle, in press). In the western U.S. a common problem is overuse of the forage resource. Livestock grazing or heavy use by big game can destroy aspen regeneration, even when a dense stand of suckers comes up after clear-cutting or fire. This is especially true on small clear-cuts or burns that attract ungulates to the heavy crop of palatable forage. Careful grazing management, especially of sheep, is necessary for at least 3 to 5 years after suckers arise so they will outgrow the reach of browsing livestock. Concentrations of big game, especially elk, can be very destructive to aspen regeneration. Most damage is done to aspen on winter and spring range. Herd size control by hunting is the most satisfactory answer if aspen is to be retained on heavily used ranges.

Several papers in last year's symposium proceedings (Samoil 1988) stated that the undergrowth of grasses and shrubs in the mixedwood forest is a severe competitor for conifer regeneration; inferred that it had no value and was only a problem; and recommended its control with herbicides. I recommend that the value of the undergrowth as wild and/or domestic ungulate forage be seriously considered.

WILDLIFE

A mixed forest of aspen, other hardwoods, and conifers contains a diversity of habitats and, as a result, many species of wildlife. The mixedwood fits that description. In the somewhat similar aspen ecosystem of the western U.S. there are about 135 species of birds and 56 species of mammals. Among them are several important game species (elk, moose, deer, and three species of grouse). Active management of that ecosystem, just as active management of the mixedwood system can be used to enhance wildlife habitat. Clear-cutting or burning mature stands of aspen benefits several species; including moose, elk, deer, ruffed grouse, and snowshoe hare; by triggering the production of more forage and a denser stand structure. Fire or clear-cutting also retards succession and retains the seral hardwood component in these systems. However, the mature and over-mature aspen forest is preferred habitat for some other species, such as bears and cavity nesting birds. Still other species, such as pine martens and red squirrels, do best in pure conifer stands. Healthy populations of many wildlife species are encouraged if the manager maintains a mosaic of habitats consisting of an array of age and size classes, of mixed stands, and of pure stands of both conifers and hardwoods. More specific recommendations are made for habitat management to favor maximum populations of individual species in DeByle (1985).

GENERAL RECOMMENDATIONS

While managing the mixedwood system for wood products, the other values and resources as a group will be best served if;

1. Clear-cuts are kept as small as practical. Instead of a minimum of 50 hectares, as now recommended, perhaps that ought to be the maximum size.

2. The clear-cuts are irregular in shape and fit into the landscape. Roads should also fit the landscape.

3. The two-stage harvesting scenario proposed by Brace and Bella (1988) be used to maximize production of both aspen and spruce in the long term. This will also ensure the perpetuation of a maximum diversity of wildlife habitats in conifers, in aspen, and in mixed conifers and aspen.

4. The mixed forest is encouraged. Forest succession is used, not fought.

5. Thinning is done only in conifer stands; the aspen will thin itself at no cost. Besides, those dense young sucker stands of aspen are excellent habitat for several wildlife species.

6. Herbicides are used only where absolutely necessary. They, like thinning, become a long-term investment with minimal return. Herbicides may do a good job of releasing conifers, but they also alter a forage-rich understory, kill potentially valuable hardwoods, and alter or destroy wildlife habitat.

7. Incentives are provided entrepreneurs to develop all values and resources in the mixedwood.

CONCLUSIONS

Aspen and aspen-conifer forests can be successfully managed for several values simultaneously. Often a treatment prescribed for enhancement of one value will enhance others as well. This very dynamic system is also quite forgiving of management errors. Even where conifers are the preferred wood producing species, a mix with aspen provides catastrophic insurance. Fire, extensive blowdown, or insect outbreaks may destroy the conifers, but with an adequate distribution of aspen in the stand, the aspen will rapidly regenerate and occupy the site. Conifers will come in again later.

I have never felt that management for multiple returns from the aspen ecosystem need be a particularly difficult challenge from the physical or biological point of view. The same applies to the aspen-conifer forest in the mixedwood. The harvest operation provides the tool, without cost, to manage this system for wildlife species that we may wish to emphasize, for enhanced forage production for either wild or domestic ungulates, for increased water yields, and even for aesthetics. Moderate sized clear-cuts that blend into the natural landscape need not be offensive intrusions by man. The road system can provide access for recreation, fishing, or hunting.

When all resource values, both tangible and intangible, are summed, I would suspect that the mixed aspen and conifer forest on these sites will be more valuable in the next one or two decades than extensive stands of white spruce. So, mange for the mix, look at the positive values afforded by the hardwoods, and try to utilize the mix of products and intangibles that this system has to offer. In so doing, the challenge will become an opportunity.

There are many potential conflicts that need to be resolved to permit successful management of this multiple valued system. Recognition of these values on the part of the managers, education of the public to assure them that you are truly managing the ecosystem with all values considered, and public involvement in the decision making process, are all necessary.

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SOME THOUGHTS ON THE ECONOMICS OF MIXEDWOOD MANAGEMENT

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ABSTRACT

The choice of aspen (*Populus tremuloides*) versus spruce (*Picea glauca*) as crop tree species, and the most efficient treatments for regenerating these species are controversial topics in the management of mixedwood stands in the boreal forest. This analysis uses a simple technique to illustrate that a 10 to 20 fold greater product value is necessary for spruce products to justify establishing spruce plantations rather than accepting inexpensive, natural aspen regeneration on medium sites. Aspen management also provides wood supply during a predicted shortage period in 50 to 120

INTRODUCTION

Thank you to the organizing committee for the opportunity to contribute to this symposium, and to Dr. Petersen for the introduction. As my biography indicates I am neither a well-established economist nor a silviculturist of the boreal forest. So what am I doing making this presentation? The organizing committee asked that I provide an analysis of hardwood versus softwood regeneration in boreal mixedwood stands that would be understandable to operational foresters. They stressed the need to review the main economic issues in terms that would be familiar to this group.

The vigorous natural suckering of aspen after harvesting mixedwood boreal forest sites provides inexpensive regeneration of this species, but it creates severe competition and thus high reforestation costs when establishing spruce plantations. Preference for spruce could be justified in the past because of the lack of processing technology for aspen products. Recent developments in this technology now provide opportunities to produce high value aspen products. These changes have made it difficult to follow the traditional preference for spruce, but left uncertainty about how reliable and acceptable natural aspen regeneration is. This analysis is designed to provide some food for thought for those of you facing this problem.

I will first clarify the perspective of this analysis and then define the managment options that are analyzed. This is followed by a description of the analysis process and the data used. The results of the analysis and comments on its interpretation follow. I will end with some cautions on extrapolating these results.

Perspective of the Analysis

This analysis has been completed for publicly owned land in the boreal forest area of British Columbia. In this province legislation requires that every area that is harvested must be regenerated to meet defined standards. There is no question whether or not regeneration costs should be incurred; the relevant questions are:

a) what should the regeneration standards be for specific sites, and,
b) what are the least-cost methods of achieving these standards?

Site-specific regeneration standards are based on management objectives. This analysis has been completed for medium productivity sites in the boreal forest which support a mixed stand of aspen and spruce or pure aspen before harvest. Timber products are assumed to be the primary management objective for these sites. Comments on the impacts of the regeneration options on non-timber resources will be made.

Management Options

The organizing committee asked that an evaluation of pure spruce, pure aspen and mixedwood options be provided. Table 1 describes the regeneration treatments that have been analyzed for each option. The high yield options have been adapted from those proposed by Day and Bell (1988) during the symposium last year in Alberta. I have attempted to keep these regimes similiar to the ones presented by Dr. Navaratil earlier in this symposium to avoid confusion.

Specific treatment methods have not been defined because these decisions are site specific and in some cases, such as site preparation for the 'assisted natural aspen'

TABLE 1. Management Options

Species to Regenerate	Treatment Name	Reforestation Treatments
Pure aspen	Natural	Surveys*
	Assisted natural	Site prepare; surveys
	High yield	Space; 2 thinnings; surveys
Pure spruce	Raw planting	Plant; surveys
	Optimistic	Site prepare; plant; surveys
	Average	Site prepare; plant; brush; surveys
	Aggressive	Site prepare; plant; brush 2 times; surveys
	High yield	Site prepare; plant; brush 2 times; space; 2 thinnings; surveys
Mixedwood	Understory protection	Careful logging; surveys
	Underplanting	Underplant spruce; careful logging; surveys

* Stocking and free-growing surveys

option, the most effective treatment is not yet known. Costs of a variety of treatments are very similiar thus this lack of definition does not greatly compromise the accuracy of the analysis.

The 'understory protection' option for mixedwood management assumes there is an adequate understory of natural spruce. Although the literature does not include many trials where spruce has been planted under an aspen stand, and there are stories of poor success with this treatment on an operational basis (E.B.Petersen, personal communications) I have included this option to illustrate its relative value if the appropriate treatments are identified.

ANALYSIS

Decision Criteria

Conventional economic analyses have used the discounted cash-flow approach. This requires knowledge of regeneration costs, growth and yield patterns, future harvesting costs, product values and the appropriate discount rate for the period of the analysis. The long time period between the outlay of reforestation costs and the returns from harvesting the stand make it very difficult to define the harvest costs and product values. The appropriate discount rate is also difficult to define over such long periods. These uncertainties make it possible to question the results of a conventional economic analysis if they are not consistent with common perceptions.

A simpler criteria which does not include future product values, harvesting costs or a discount rate is the regeneration cost per volume of wood produced. Options having lower regneration costs per cubic metre of volume are preferred. As Table 2 illustrates, although this criteria is easy to understand and interpret, it does not incorporate the impacts of differences in the rotation ages of options. Longer rotations with more volume production have lower costs per cubic meter of growth with this criteria.

This can be overcome by discounting the volume in the same way the net product value is discounted in a conventional analysis, (Pearse et al., 1986) or by calculat-

TABLE 2. Example of decision criteria

	Example 1	Example 2
Reforestation cost ($/ha)	500	500
Volume (m^3/ha)	315	540
Rotation age (years)	70	120
Cost/m^3	$1.16	$0.90
Mean Annual Increment (m^3/ha/yr)	4.5	4.5
Cost/m^3 MAI	$111	$111

ing the annual production or the mean annual increment for the option. The latter represents the regeneration cost required to create a cubic meter of wood annually. This criteria most accurately represents the silvicultural decision when the perspectives of timber supply from a forest area are considered (assuming no supply constraints due to age class distribution).

Since the question posed in this analysis is not an investment question of 'Should we practice reforestation on these sites?' but rather the question of 'What are the best reforestation standards in the boreal forest?' we are free to use alternative decision criteria. The cost per cubic meter of mean annual increment can be calculated with only reforestation costs and yield data which are relatively well documented. The results can be used to indicate the difference in the net value of the product that would be required to offset differences in reforestation costs.

Data

Lack of data is the most common reason given for not attempting to analyze forestry decisions. This is especially true in the frontier areas of this province. However, let's remember that these decisions must be made. Even if we're doing it in our heads, some form of data has to be used. The analysis process documents the data that is used and ensures our calculations are correct.

Reforestation and stand tending costs

Actual treatment costs incurred in local silvicultural programs during 1988 were used in this analysis. Table 3 lists these costs for each option. On-site and supervision costs are included but overhead is not. The planting cost includes the cost of growing and transporting the seedlings.

Successfully establishing spruce plantations in boreal forest conditions is a relatively risky silvicultural task. Low survival and poor growth often occur on these sites. Additional regeneration costs retreatments are included for the plantation options to account for these risks.

Growth and Yield

Unfortunately there will not be a separate presentation on the relative growth and yield of aspen, conifer and mixedwood stands in boreal conditions. This topic deserves a presentation of its own. A summary of various sources is provided in Table 4. A 'base case' analysis is provided using 'middle of the road' values. Sensitivity analysis will test the impacts of assuming relatively high spruce and low aspen yields.

Results

Table 3 provides a summary of the calculated reforestation cost per cubic meter of mean annual increment using the base case yield projections for the management options that were analyzed. In the least cost scenario for spruce establishment, where planting without site preparation would be successful, this option must produce a net product value that is approximately 20 times ($195/$9) greater than the cheap aspen natural regeneration option in order to justify preferring spruce over aspen. Since it costs 20 times more to produce the same annual volume growth, the spruce volume must be worth approximately 20 timmore than aspen to justify the increased cost. This difference will be referred to as the breakeven net product value differential in this analysis.

It is important to recognize the high risks of failure with the least cost option. The breakeven net product value differential must leap to approximately 40 times if the high probability of failure with the planting only option is considered, and retreatment costs are included in the analysis. When retreatment costs are included in the analysis the high yield spruce option becomes more favourable because of its high success rate and high volume production. This result supports the operational perspective that if you're going to establish spruce on these sites you had best plan to manage it aggressivvely to get maximum production for your costs.

This analysis indicates the mixedwood options should be promoted over the pure spruce options if spruce regeneration is available and preferred. It should be stressed that

TABLE 3. Calculation of reforestation costs per cubic meter of mean annual increment

Option	Reforestation Cost ($/ha)	Rotation Age* (yr)	MAI (m^3/ha/yr)	$/$m^3$ MAI
Pure aspen				
Natural	40	75	4.5	9
Assisted	340	75	4.2	81
High yield	740	40	6.0	123
Pure spruce**				
Plant only	810	130	4.2	195
	1600-1800	130	4.2	380-434
Optimistic	1110	120	4.3	257
	1600	120	4.3	372
Average	1410	120	4.5	313
	1910	120	4.5	424
Aggressive	1710	120	4.5	380
High yield	2310	70	6-8	288-385
Mixedwood				
Understory protection	490	120	8	61
Underplanting	1300	60/120	8	163

* Rotation ages based on maximum volume production and piece size were used in this analyis. Regeneration delays are included in this rotation age.

** The impact of increased reforestation costs to account for plantation failures are shown in the second line of the Plant only and Optimistic options.

realizing the relatively low regeneration costs and high yields used here will require improvements in existing operational practices.

Since the data for these analyses is very preliminary, and the results do not support traditional practices, it is important to evaluate ranges of outcomes, or 'What if..?' scenarios. Table 5 compares the results of the previous analysis with a scenario where the lowest aspen yields and the highest spruce yields are achieved. In this view of the future the break-even net product value differential for spruce is reduced to 16 times that of aspen, and all spruce plantation options have similiar outcomes. The high yield spruce option should still be preferred because of its shorter rotation and the probability of achieving larger piece sizes.

To complete this analysis it is important to question what the likelihood is that spruce products will be 10 to 20 times more valuable than aspen in the future. First let's review current product values. Table 6 summarizes this information. Note that in locations where processing facilities exist to manufacture products from both species there is at best a 2 fold difference in the value of raw logs. This relationship doesn't improve much when you compare the value of finished products. Remember: aspen is a high quality fibre that can be used to produce high value paper and composite board products.

Predicting future values is difficult if not foolish. There is no doubt that product values will increase, but will the increase be different for spruce versus aspen? Perhaps

TABLE 4. Summary of yield projections for medium sites in Canadian boreal forests

Species	Data source	Rotation Age (years)	Merchantable Volume (m^3/ha)	Mean annual Increment (m^3/ha/yr)
Aspen	Saskatchewan	65	175-196	2.8
	Ontario	55	271	5.3
	B.C.	80	213	2.7
Spruce	Saskatchewan	75	230-315	3.1-4.5
		110	280-455	2.5-4.2
	B.C.	110	324	2.9
	Managed stand	50	330	6.6
Mixedwood	Ontario			3.6-5.4
	B.C.	120	321	2.7

Note: These values are greatly influenced by differences in utilization standards and rotation age definitions. This information is only intended to provide the reader with a perspective on the ranges in this data.

SOURCES:

Saskatchewan: Kabzems, A., A.L. Kosowan and W.C. Harris. 1986. Mixedwood section in an ecological perspective. Saskatchewan Parks and Renewable Resources, Forestry Division and Canadian Forestry Service.

Ontario: Plonski, W.L. 1981. Normal yield tables (metric) for major forest species of Ontario. Forest Resources Group. Ontario Ministry of Natural Resources.

British Columbia: Jim Goudie, Research Branch, B.C. Forest Service, personal communication.

Managed spruce: Berry, A.B. 1987. Plantation white spruce variable density volume and biomass yield tables at age 60 at the Petawawa National Forestry Institute. Government of Canada. Canadian Forestry Service. Petawawa National Forestry Institute. Information Report PI-X-71. 7 p.

the best approach is to compare the cost of hardwood and softwood fibre in countries where spruce and aspen are grown and processed, and which have already experienced fibre supply shortages and increases in prices. Table 7 shows the similiarity in fibre costs for hardwood and softwood species in Sweden and Finland.

This information indicates there is little reason to believe there will be large enough differences between aspen and spruce product values to justify incurring the very high and risky costs of establishing spruce plantations on medium sites where natural aspen regeneration is vigorous and well distributed.

TABLE 5. Comparison of base case and high spruce/low aspen yield scenarios listed from lowest to highest cost/m³ MAI.

Base Case Scenario Option	Cost/m³ MAI	Breakeven Value	Product Differential	High Spruce/Low Aspen Cost/m³ MAI	Yield Scenario Option
Natural aspen	9	-	-	16	Natural aspen
Assisted aspen	81	-	-	123	High yield aspen
High yield aspen	123	-	-	146	Assisted aspen
High yield spruce	288-385	32-43*	16	261	Average spruce
Optimistic spruce	372	41	16-17	256-278	Optimistic spruce
Aggressive spruc	380	42	18	285	Aggressive spruce
Plant spruce only	380-434	42-48	18-20	292-325	Plant spruce only
Average spruce	424	47	18-24	288-385	High yield spruce

* Calculated as follows: 288/9 = 32; 385/9 = 43

TABLE 6. Current forest product values in British Columbia

Species	Stumpage ($/m3)	Purchased Log Price ($/m3	Net Product Value ($/M3)
Aspen	$0.25-0.50	$20-25	$0-75
Spruce	$6-7	$25-34	$0-130
Difference	12-28 fold	0-2 fold	0-2 fold

Sources: Bayard Palmer, Woodbridge Reed and Associates, Vancouver, personal communications Lousiana Pacific, Dawson Creek, personal communications Ainsworth Lumber, 100 Mile, personal communications

MANAGEMENT IMPLICATIONS

Silviculture Prescriptions

Aspen should be accepted as a crop species on medium sites in the boreal forest where vigourous, well-distributed suckering can be expected. Adequate density and growth rates can be achieved without reforestation treatments on many sites. Further research is needed to investigate the impacts of juvenile spacing.

Further research is also needed to identify appropriate treatments to encourage aspen suckering where poor distribution of mature aspen prior to harvest, or inhospitable environmental conditions create patchy distribution of regeneration. Once these treatments have been identified an analysis should be completed to compare these options with converting to pure spruce.

Where possible, understory spruce regeneration should be encouraged and managed. This option provides the greatest volume production at a relatively low cost.

Intensive, high yield silviculture should be practiced on sites where spruce plantations are established. Prompt control of competing vegetation and density management are necessary to realize maximum productivity from these sites.

Timber Supply

The northern timber supply areas are expected to experience conifer timber shortages in 50 to 100 years (Darrell Robb, TSA Planning Coordinator, Prince George Forest Region, personal communication). Spruce stands created by artificial regeneration over the next 10 years would likely be merchantable by this time, but they would certainly not produce their maximum volume or economic potential. On the other hand, aspen stands would be mature and available for harvest. The longrun timber supply situation should be considered when decisions are made to regenerate species with widely differing rotation ages.

Given the uncertainty surrounding the future value of different wood products it is a wise strategy to include a diversity of species and thus potential products within a supply area. Accepting vigorous natural regeneration of aspen on sites where aspen productivity is acceptable while establishing spruce mixedwood plantations on the remaining sites will result in a diversified 'portfolio' of species and thus products to take advantage of opportunities in an uncertain future marketplace.

Non-Timber Resources and Environmental Impacts

Successful establishment of spruce plantations on medium sites in the boreal forest requires aggressive site preparation, planting and brushing treatments. Competing 'non-crop' vegetation such as reedgrass (*Calamagrostis canadensis*), aspen and a number of shrub species must be controlled to ensure the crop seedlings survive and grow. These species have significant values as forage for range and wildlife species and as cover and habitat for a diversity of small mammals. Establishing spruce plantations simply may not be an acceptable strategy where non-timber resource values are high.

The site preparation and brushing treatments required to establish spruce plantations often include significant alteration to the soil environment and the use of chemical herbicides. The environmental impacts of these treatments may not be acceptable if they are applied throughout the forest.

CAUTIONS

This analysis is relevant for medium sites in the boreal forest where natural aspen suckering will be vigorous and well distributed. It does not apply to poor or good sites where aspen productivity is significantly lower than spruce. Nor can these results be transported outside the boreal forest where the relative productivity of aspen and spruce are undoubtedly different, and where other species (such as lodgepole pine) should also be considered. Differences in treatment costs and probabilities of treatment outcomes will also influence the acceptability of aspen on other sites.

This analysis is also not a justification to 'log it and leave it' on all sites in the boreal forest. The challenge for silviculturists in this area is to recognize the site and stand

TABLE 7. Fibre price in Sweden and Finland

Country	Hardwood Fibre Price (US$/tonne)	Softwood Fibre Price (US$/tonne)
Sweden	$116	$122
Finland	$127	$132

Source: Woodbridge, Reed and Associates. 1988. Canada's Forest Industry the next twenty years: prospects and priorities Volume 1 Strategic Analysis.

conditions at the pre-harvest stage that will result in vigorous suckering of aspen after harvest. Spruce plantations should be established on sites where aspen suckering is unreliable. You're not off the hook in terms of reforestation up here in the north because of this analysis; but your focus should shift to the difficult task of successfully establishing spruce plantations mixed with natural aspen only on those sites where natural aspen regeneration cannot be relied upon.

I'd like to close with a word of advice to the silviculturists in the audience, and to anyone else who was little access to information on developments in forest products processing technology: it's changing fast, and you should find a way to keep up with it. If we don't stay informed we will soon find ourselves fighting to grow a crop that no one will buy.

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STRATEGIES FOR MIXEDWOOD MANAGEMENT: A COMPENDIUM

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I would like to summarize the highpoints of today's discussion, at least as I saw them. I'd like to reinforce the technical messages, and summarize and integrate these with what we know in general about the subject of mixed wood management. I'd like to place all this in a decision-making context and then try to help you reach your own conclusions about the management options that are before us.

Jamie Benson focused on inventory and made the point that we had to have better inventory and a stronger mixedwood classification system if we were ever going to make some intelligent management decisions in this forest type. He held out hope that we could increase our knowledge with tools, such as remote sensing models and hardware, that are now available to us. Craig Delong gave us an overview of the ecosystem dynamic of the mixedwood forest and put forward the view that we must understand this dynamic and use the diversity of this ecosystem as an ally for increasing productivity.

Stan Navratil talked about regeneration in the mixedwood forest and suggested that we have basically three options for using the full site potential of this type: we can either grow hardwoods, we can grow for mixedwoods, or we can grow conifers. To make sensible choices, we need to understand what the goals of management are. Whether we like it or not, the hardwood component of our mixedwood forest is increasing. Stan talked about nature needing to be ridden, not driven, and that we must align the objectives of management with the inherent capacity of site.

Tony Sauder talked about harvesting and commented that often a lot of white spruce understory is left after harvesting mature aspen and conifer. For residual regeneration to work, five caveats were suggested. It now seems important that:

1) Mechanical felling equipment be used;
2) Felling equipment be well matched to both the timber and the terrain;
3) Trail and landing layout be well planned;
4) Supervisors be on-site (and committed to achieving results);
5) Results be shared.

Jan Volney reminded us that there is a large quantity of pest-related information available on the mixedwood forest, and that many of the pest management tools have been or can be easily developed; that we need to know the goals of management to direct the tools available; that expert systems are developed and available to help; and that pest management of the regenerated forests may be a very smart thing to do. He talked about logical strategies for pest management.

Norbert De Byle talked about integrated use and provided some insights on the other non-timber demands of the forest such as livestock, aesthetics, and water yields. He suggested that, in the U.S., no single value dominates and controls ecosystem management. He suggested, probably somewhat facetiously, that one will get conifers in the mixedwood forest — one just has to protect them long enough.

Cindy Pearce shared some thoughts on economics and put forward a method of economic analysis that she hoped would appeal to the forestry practitioner. Cindy talked about uncertainties, both biological and financial, and developed more of an estate planning approach to the economics. Cindy suggested that the relevant decision-making variable ought to be the cost of creating a cubic metre of mean annual increment. She decided not to go into the more traditional time and timber value arguments.

The Oxford system of decimal classification (Table 1) suggests to me that our panel have virtually addressed the "A to Z" of forestry for the mixedwood forest. We have talked about seven of the ten basic factors that we need to

consider when talking about forestry. We did not talk about marketing, and we did not talk about products and utilization. There are some other social aspects that ultimately need to be considered.

Table 1
Lead Headings Of The Oxford System Of Decimal Classification For Forestry

	0.	Forests, forestry and utilization
✓	1.	Factors of the environment
✓	2.	Silviculture
✓	3.	Work, harvesting, logging, transport
✓	4.	Forest injuries & protection
✓	5.	Forest management, economics, administration & organization
	7.	Marketing
	8.	Forest products and utilization
✓	9.	Social economics of forestry

We know a lot about mixedwoods

We do know a lot about forestry and forestry management in the mixedwood region. If I had any worry with what we know about this forest, it is that we have accumulated much fact and information, but this information has not matured into knowledge, wisdom, and, in turn, better forest management. We must communicate facts to let them grow and become information. You have to pool information with acquired truths and principles so these, in turn, can become knowledge. That knowledge with insight leads to wisdom and it is wisdom that we need to guide forest management decision (Table 2).

Table 2
The Maturation of Understanding

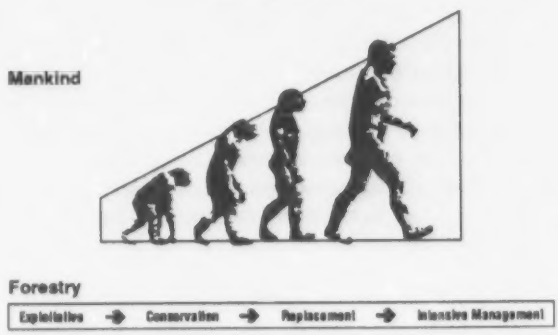
- **FACTS** when communicated become information
- **INFORMATION** pooled with acquired truths & principles becomes knowledge
- **KNOWLEDGE** with insight leads to wisdom
- **WISDOM** is what we need for good forest management
- **CHALLENGES** both the user and supplier of information to link with truth & insights or at least ask these questions

The disciplined use of information is virtually important for forest management decision-making in the boreal mixedwood zone of Canada. The need for mature viewpoints challenges both the supplier and the user of information. It challenges the user to make sure that the right questions are being asked: "Is this fact and this information going to help me build the knowledge and the wisdom that I need to make the forestry decisions that are important?" It challenges the supplier to make sure that the information being provided has the capacity to grow into knowledge and wisdom and therefore be helpful. I am reminded of words from Thomas Elliott's poem "The Rock". Elliott laments "where is the knowledge we have lost in information, where is the wisdom we have lost in knowledge" and then concludes on a real downer, "all our knowledge brings us closer to our ignorance." Let's not fall into the rather arrogant trap of looking for technical solutions when we are looking for technical answers; the solutions occur on a more social plain.

The pearls of wisdom

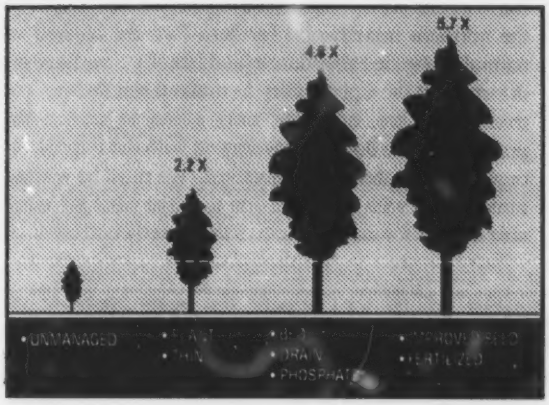
Let me share with you what I see as some of our bright lights of wise forestry thinking. In the same way that man has stood erect, so has forestry thought evolved (Figure 1). In forestry we have had our exploitation phase. Some may say we are still in it. Gradually, the ethics of conservation and sustained yield are evolving, growing slowly over time into an ethic of intensive forest management. I suggest that it is as inappropriate to think we can now exploit our mixedwood forest, as in days of old, as it is unlikely that man will ever drop back to all fours and sustain himself on a diet of bananas. I don't think the exploitation option is one that is rational for us, now. Environmentalists, our public, our whole industry won't allow that, so let's not debate at length the extensive options.

Figure 1
Man and Forestry



In a biological sense, we know an awful lot about how trees and stands grow. In Connor Boyd's 1985 talk to the University of Alberta, he suggested that growth from

Figure 2
Options: The Silviculture Opportunities



From: Boyd (1985)

southern pines with management is some 5.7 times that of the wild forest yield without management (Figure 2). John Gordon and others suggest that if you do everything right, in a biological sense, there may be a 22-fold increase under growth chamber conditions. If you don't believe that, you should see some of Nick Wheeler's results with extended photo-period and the like. There is an awful lot of biological things you can do to increase growth and the results are truly impressive. My friend, Stig Hagner from the Swedish Cellulose Company, Sundsvalt, Sweden, suggests that growth with intensive forest management in that country may be somewhere around six times that of wild forest growth, independently verifying Connor Boyd's earlier referenced views.

That substantial increases in forest growth occur with management is well and truly embodied in our knowledge base; however, we are not wise enough, it seems, to use this information at this time.

Bottom-lining investments in silviculture

Cindy Pearce, earlier today, expounded on some of the methods for economic decision-making in forestry. Clearly, to make wise silvicultural decisions, we have to understand the revenue and cost side of silviculture. Just knowing the biology is not enough; it leads one down the road of practicing forestry because it's good for the soul, but not necessarily good for society or good for the pocket. We are going to have to understand costs of production, on one hand, and likely revenue on the other.

Connor Boyd has examined forest investment on site three Douglas-fir land in western Washington (Figure 3). When net present value and discounted dollars are applied to revenue and costs, for this particular example, we develop an appreciation of silviculture for a range of opportunities that include planting, planting and thinning, and planting. thinning and fertilizing. The best financial decision in this case is one that doubles growth. What a spectacular impact such an investment would have on forestry. Actual volumes are only limited to the amount of land you harvest and the amount of dollars you have to invest in silviculture. If we were to double our allowable cut in British Columbia, as in this example, we could take our annual harvest up to 150 million cubic meters, perhaps in a time frame as short as three or four decades. We don't have a timber supply problem if we get active with the silviculture opportunities that are available to us. First, there is a need to better understand the logic for investing in silviculture.

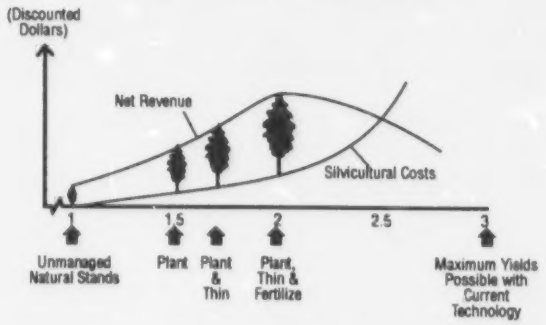
The decision making context

Carefully devised investment plans are needed if we are to meet public and community expectations.

CONCLUSIONS

I have been a silviculturist long enough to know that there is not just one ideal answer. Some insights and applications are identified in Table 3. However, the knowledge base is rich, probably richer than we are wise enough to apply. For instance, if we analyze the economics of silvicultural investments in the mixedwood zone, and the results show negative present net values — then we had

Figure 3
Costs and Revenues: The Financial Opportunities For Silviculture



From: Boyd (1985)

better look for the structural impediments that cause this to be so. I think we need technical answers but the answers are not technical. The knowledge base does need regional calibration and knowledge needs fine tuning. The technical things should be done with the big picture in mind, though, to facilitate the growth of knowledge and wisdom.

What are the silviculture financial or social expectations of this mixedwood forest? I must confess that I don't know; I know what they are from my perspective but I don't know what the community sense of purpose is. I suggest that we better find out and ask these communities what it is that they want before we get carried away with the technical discussion about what some of the technical opportunities are.

In conclusion, I would like to take some license from the inscription on Wende Wilkie's headstone. I believe in the northern mixedwood for here "we are blessed with natural and varied abundance (and I think).... we have great dreams and the opportunity to make these dreams come true." We are, however, only going to realize these potentials if we don't get overawed with the impediments or ambiguous about the objectives. We must be willing to move ahead with some passion to make what are reasonable dreams for management of the mixedwood come true.

Table 3
A Summary of the Main Messages

	Insight	**Application**
Knowledge	The knowledge base on how trees and stands grow is rich	We don't have to "re-invent the wheel" in order to make good management decisions in the mixedwood
Calibration	We need technical answers but the answer is not technical	• The knowledge base does need regional calibration, methods need fine tuning • Technical things should be done with the "Big Picture" in mind to facilitate growth into knowledge and wisdom
Social Expectations	Mechanisms for strategic planning exist from which a common sense of purpose and objective can be derived	• Effective management of the mixedwood requires that a consensus of purpose be arrived at • What is the silviculture, financial, social expectation for this forest?

BANQUET REMARKS BY THE HONOURABLE DAVE PARKER
MINISTER OF FORESTS

(TUESDAY, SEPTEMBER 12, 1989)

Good evening.

Again it is my pleasure to speak to you this evening after what I feel was a most productive day.

Session One on 'The Mixedwood Challenge' was very informative, as was Session Two, on "Mixedwood Management Decisions: Elements in the Equation".

This morning, in my brief opening remarks, I outlined an historical perspective of British Columbia's new interest in deciduous species, the surge in investments in plants to produce products from aspen, and our eventual entry into the field of mixedwood.

The information we have attained from your learned observations and extensive experiences in mixedwood harvesting will help us develop effective policies for the harvesting, renewal and management of mixedwood stands.

For instance, our policies must consider the fact that deciduous species, such as aspen, grow faster than our coniferous species. I understand that poplars can have a far shorter rotation — just about 30 years — than our conifers.

We need to do more research to ensure that correct species are planted on suitable growing sites. With the big difference in age class, we have problems.

Which method of harvesting and which type of species should be used in reforestation — deciduous, coniferous, or both — are only some of the basic questions we have to address. To answer them, we have to look at the sites, their biogeoclimatic zone, their economic value to the province, the demand for their products, the markets.

At present, our policy is to reforest coniferous stands with coniferous species and deciduous stands with either deciduous or coniferous species.

As you are aware, British Columbia's forest industry accounts for more than 45 per cent of the value of shipments from all manufacturing industries in the province. Approximately 75 per cent of our forest products are exported.

At the national level, the province accounts for approximately 40 per cent of some $20 billion of exports in the forestry sector.

In terms of the world market, our province has 32 per cent of softwood lumber market, more than 14 per cent of the pulp market and more than 10 per cent of the newsprint market.

However, because our export markets are highly cyclical and subject to increasing pressures for protectionism, we must seize every opportunity to stabilize and expand our industry by:

- diversifying export destinations;
- expanding specialty, secondary and tertiary milling of solid wood products;
- updating our inventory of fibre suitable for pulp and paper products; and,
- using the previously non-commercial species, such as aspen and alder.

The last is the reason why we must look at mixedwood.

I mentioned this morning the investments being made in our province in chemi-mechanical pulp mills, with aspen as a desirable raw material.

But we need to move further . . . to use all species in mixedwood stands for a variety of finished products.

Alberta now has a pulp mill that is using a combination of aspen and spruce as the raw material to produce a high-value product. Tackama Forest Products uses balsam poplar and spruce in plywood.

We also need to harvest older stands, which have problems of decay and stain, and develop uses which minimize waste, such as for use in waferboard plants and pulp mills.

In British Columbia we need to develop strategies with regard to mixedwood management, because mixedwood will have a significant impact upon our resource and our economy.

The mixedwood challenge is dynamic.

There is the challenge of genetic improvement — to increase the yield of our mixedwood stands.

There is the challenge to develop harvesting systems for mixedwood stands so that the understory species that are not being harvested are not damaged.

The white spruce understory in the aspen stands is difficult to regenerate.

Therefore the protection of the understory will reduce the need for artificial regeneration and long-term tending of coniferous plantations.

Without suitable methods of harvesting, there is the danger that the volume of white spruce will steadily decline.

There is also the challenge to initiate forestry research, now concentrated on coniferous species, into the deciduous species.

The British Columbia Forest Service has now changed direction — from research into how to eradicate deciduous species, into research into how to grow and reproduce aspen.

We also have the challenge to harmonize our forest management with programs of other ministeries, such as the Ministry of Environment, for the integrated use of our mixedwood stands.

We also need to use mixedwood stands for range. The former practice of burning aspen to provide for range was wasteful of the resource.

As you are aware, the Forest Service has stewardship responsibilities for all 'provincial forests' — 80.76 million hectares of Crown provincial land, or 85 per cent of the province's total area.

However, as only about one hectare in four of the province's total area — or 22.6 million hectares — is available for timber harvesting, we must make best use of every available hectare.

And every year, roughly one per cent of this available productive forest land is harvested to provide an allowable annual cut is 72 million cubic metres.

Because we have just started to harvest the deciduous species, we have yet to include the allowable annual cut of these species in our provincial total.

A bigger portion of the provincial allowable annul cut is today being allocated to our newly expanded Small Business Forest Enterprise Program.

I would like to talk about this program now for a few minutes.

We have expanded our Small Business Forest Enterprise Program and we expect to sell about 10 million cubic metres of timber annually under the program in the next five years.

The program has three primary objectives:

First, entry. We are providing entrepreneurs the opportunity to establish a new business in our forest industry through competitive sales.

Second, diversification and competition. We are selling a substantial volume of timber to promote and encourage the production of specialty and higher-valued, solid-wood forest products. We are also selling as much timber as possible through open competition to allow the most efficient entrepreneurs to win timber sales.

Third, profit. We are managing this program on a business-like and profit basis. We will return a dividend to the public for the timber sold. A new section in our Forest Act now allows timber sales to encourage and promote further manufacturing of timber and forest products.

We can now award timber sales, with five-year terms — 10 years in some instances — to entrepreneurs who submit the best proposals involving secondary manufacturing.

One company in Lillooet has received a timber sale licence under the program and will now be expanding its dry-kiln capacity to produce specific metric-sized, pre-cut, component lumber for use in traditional and pre-fabricated housing industries in Japan.

It is also producing select stock for the joiner market in the United Kingdom.

Its expansion will include equipment for finger-jointing, laminating, edge-gluing and other manufacturing.

Another specialty wood-manufacturer, this one in Penticton, has got a timber sale licence and is producing a range of pine furniture, including wall units, bookcases, tables, chairs and beds.

All units are packaged flat in ready-to-assemble kits.

Our new forest policies call for the reduction of the allowable annual cut of major replaceable licences, such as forest licences, and the Crown-land portion of tree farm licences, by five per cent. This volume is being reallocated to the Small Business Forest Enterprise Program so that it can be expanded.

The program will also receive additional volume when there are ownership changes in major licences. With our expansion of the Small Business Forest Enterprise Program, we would like to see small business ventures taking a serious look at using coniferous tree species and mixedwood for their products, particularly in this region of the province.

There are great opportunities here and we would like British Columbians to seize them. The Forest Service has a mandate, under the Forest Act, to "encourage a virogous, efficient and world competitive timber processing industry in the province".

Our Industry Development and Marketing Branch analyzes opportunities for expanding our forest products industry.

Our goals are to:

- minimize trade barriers;
- provide liaison for investors;
- ensure industry proposals having greatest economic merit are selected; and,
- improve legislation to further our forest products industry's vitality.

We have tremendous opportunities to diversify our export destinations and expand speciality, secondary and tertiary milling of solid-wood products.

We are pursuing these opportunities.

We have sponsored seminars to identify the needs of the secondary manufacturing sector.

Through this approach we hope to encourage research, development and technology transfer initiatives for remanufacturing and secondary manufacturing.

We are linking our research and timber harvesting policies and programs more closely to industry development.

In closing, I would like to say that this mixedwood symposium could not have been sponsored at a more appropriate time. We are today well on our way in developing a more diversified, stable and productive forest industry. Mixedwood management and development are the next logical steps for us to take in our approach to reap the benefits of our great forest resource.

We have lots of work to do, particularly in the areas of research, development and technology transfer. At the same time we must maintain the productivity and future ecological use of our mixedwood forests.

With the better understanding and the strong friendships that are being established at this mixedwood symposium, I am confident that we will be able to better manage our mixedwood forests, increase our productivity level, enhance our environmental issues, and endeavour to plan for our future and that of our grandchildren.

Thank you for your valued contribution to this symposium and I hope the rest of your stay in Fort St. John will be pleasant and enjoyable.

INPUT-OUTPUT ANALYSIS OF THE FOREST UTILIZATION AND REPRODUCTION IN THE UNION of SOVIET SOCIALIST REPUBLICS (ECONOMIC AND ECOLOGICAL ASPECTS)

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THE ROUNDWOOD RESOURCE

The volume of roundwood removal and its distribution by regions depend on the following factors:

1. Demand for timber products of final consumption realized by sale and housing construction. The existing solvent demand of population can increase the consumption of some kinds of timber products two or three times (furniture, paper products, books, residential houses, etc.);

2. Wood consumption structure, reflecting the distribution of logs among different fields of wood utilization;

3. Raw materials potential estimated by the harvestable timber volumes;

4. Transport accessibility of the forest resources defined by the available rail-network, rivers for floating logs and roads;

5. Investment policy of the State (the volume of capital investments and its distribution among forest industries and forestry);

6. Technical changes in wood-working industries that allow to utilize all forest species and wood waste;

7. Forms of production organization represented by different types of enterprises with different levels of concentration, integration, cooperation and specialization;

8. Economic relations forming interconnections of enterprises and their higher institutions, State budget, banks, consumers and suppliers.

Let us consider the development of forest industries in the regions rich in forests where forest resources are represented by mixed forest stands. The regions rich in forest cover the European North, the Urals, Western Siberia, Eastern Siberia and the Far East. In these regions, forest industries and forestry are managed by the Union Ministry of Forest Industries. These regions provide a logging volume of 220-230 million m³ (about 60% of the total roundwood harvest).

In the poorly forested regions, forest industries and forestry are managed by the Republic Ministries of Forestry.

Let us now consider the economic characteristics of the forest industry in the regions rich in forest using the Input-Output Analysis (Figure 1).

The roundwood harvested in the regions rich in forest is to meet mainly the all-Union demands for timber and to be distributed by the centralized bodies along the following lines of final consumption: (%)

- construction - 11,
- pulp and paper production - 15,
- mining industries - 3,
- package - 17,
- furniture - 8,
- machine-building and wood-working - 6,
- maintenance and repair - 4,
- telegraph-poles - 1,
- internal market - 4,
- export trade - 13,
- fuel - 18.

The logging volume of 230 million m³ included 192 million m³ of industrial roundwood, including, in its turn, 88 million m³ of sawlogs, 37 million m³ of pulpwood, 7.8 million m³ of pitprops, 6.7 million m³ of veneer logs.

Table 1. Forest Resources in the Regions Rich in Forest Their Distribution by Species

REGIONS	FORESTED AREA (million ha)		GROWING STOCK (million m³)					
	Total	Coniferous Species	Total	Exploitable Stock				
				Total	Coniferous Species	Spruce Fir	Pine Cedar	Larch
The European North and The Urals	106.8	82.4	13.0	7.6	6.2	4.9	0.9	0.4
Western Siberia	90.3	57.3	11.0	7.2	4.8	0.3	3.7	0.8
Eastern Siberia	241.7	191.6	29.6	20.0	18.3	0.4	5.1	12.8
The Far East	270.3	195.5	22.0	14.8	13.1	4.4	1.2	7.5
Regions Rich in Forest (total)	709.1	526.8	75.6	49.6	42.4	10.0	10.9	21.5
The USSR (total)	810.9	560.0	85.9	51.7	43.3	10.6	11.2	21.5

Figure 1.

Production Resources And Output In Forest Industry

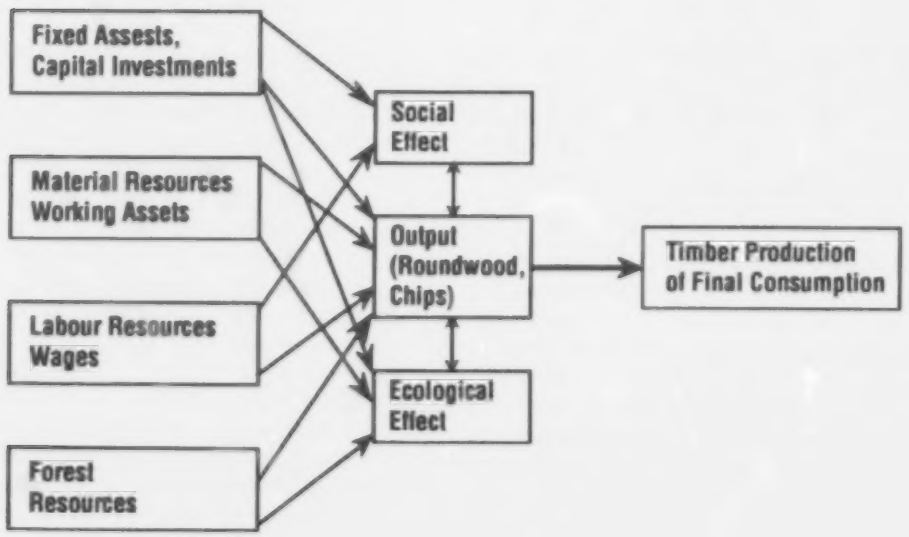

TABLE 2. Allowable Cut And Its Use By The Regions Rich in Forest.

Regions	Allowable Cut (mln. m³)			The Allowable Cut Used (%)			Thinning (mln. m³)
	Total	Including		Total	Including		
		Conifers	Deciduous Species		Conifers	Deciduous Species	
The European North and The Urals	171.3	107.6	61.6	75.8	89.1	54.8	5.4
Western Siberia	103.5	49.3	54.1	27.7	37.9	18.5	2.1
Eastern Siberia	174.2	125.6	48.6	35.1	44.0	12.0	2.3
The Far East	103.4	85.9	11.8	32.6	36.7	9.9	1.3
Regions Rich in Forest (total)	552.4	369.4	176.1	41.8	48.1	31.3	11.1
The USSR (total)	634.2	396.9	221.9	50.1	56.7	38.2	47.8

Forest enterprises produce also 12.0 million m³ of wood chips from waste wood.

The roundwood is delivered to consumers by rail - 56%, by floating - 35%, by trucks - 9%. The mean distance of roundwood transportation amounts to 1800 km.

The raw materials potential of the regions rich in forest is shown in Table 1. This table indicates that 95% of the entire exploitable timber volume may be referred to the regions rich in forest (northern and eastern forests) but economically, their accessible resources amount only to 30-35 billion m³ (60% of the exploitable volume).

The regions rich in forests are represented mainly by mixed stands where coniferous species are cut more intensively than deciduous species and larch due to lack of demand for these timber products and difficulties with the floating of deciduous trees and larch.

As a result, in many regions of northern and eastern forests, selective cuttings are carried out, i.e. only coniferous trees (pine, spruce, fir, cedar) are felled, and deciduous ones are left on the felling sites, considerably impairing the ecological conditions of the forest stands.

The allowable cut and its use are shown on Table 2.

It is necessary to pay attention to the problem of deciduous forest exploitation in the European part of the country where only 50-60% of the allowable cut for these forests is used. It considerably decreases not only the efficiency of logging but also the productivity of forest stands estimated by their current annual increment equal to 1.4-1.7 m³ /ha.

The Fixed Assets and Capital Investments in Forest Industry.

The technical development of the forest industry is determined by the value of fixed assets and annual capital investments. The estimated total value of fixed assets belonging to the Ministry of Forest Industries amounts to 24 billion roubles, out of which 7.45 billion roubles are slated for logging.

The unit capital investments in logging amount to 32 roubles/m³ . Besides, there are additional capital investments in the development of social infrastructure (housing, medical, trade services, etc.), which make up 20 roubles/m³ .

There are significant differences in the unit capital investments by regions. To cut 1 m³ in Siberia, it is necessary to invest two or so times more than in the poorly forested regions.

The fixed assets in logging have lost their value by 40%, due to depreciation of machinery that makes the problem of the machinery renovation very serious.

The northern forests are exploited mainly through concentrated clear cuttings on the basis of tracked skidders and trucks.

The annual capital investments in logging amount to 400-500 million roubles, that is two or three times less than the normative ones. So the rate of capital renovation is rather low.

In the northern forests, the most widely used technology of logging is tree hauling to low landings where the treesare cross-cut, graded and piled before delivery to the consumers according to centralized distribution.

As for logging equipment, the following machines are used:

- trucks - 17,725 pcs.,
- railway rolling stocks- 2,425 pcs.,
- skidding tractors - 25,077 pcs.,
- felling machines - 2,100 pcs.,
- felling-skidding machines - 1,400 pcs.,
- limbing devices - 5,700 pcs.,
- timber loaders on forest sites - 8,100 pcs.,
- cranes at lower landings - 4,700 pcs.,
- semiautomated lines for cross-cutting - 1,300 pcs.

The above mentioned system of machinery ensures a 40% level of labour mechanization; manual labour prevails on cutting sites and lower landings.

Capital investments in logging are financed at the expense of the depreciation charge (70%) and profit (30%). The depreciation rates are stable in time (years) and vary with the types of machinery used.

It should be mentioned that one of the difficult problems of logging is road construction in the areas of extensive marshes and peatlands (30%). In these areas, winter roads are used for hauling. In some areas, it is expected to haul at tree lengths to the consumer yards (sawmilling, pulp and paper enterprises).

Labor Resources and Wages.

The forest industries have been, in many cases, the first ones to develop the sparsely populated areas in the European North and Siberia. And in these areas, the problem of labour supply remains rather difficult and the level of labour fluctuation is the highest one compared to other industries.

The total staff of the forest industry enterprises is 1,583,000 persons, including 1,353,000 workers.

407,000 persons are engaged in logging operations (348,000 of them of are workers). The annual labour productivity in logging amounts to 660 m³/man, estimated as a ratio of annual volume of roundwood removal to the number of workers engaged in logging.

The mean monthly wage in logging amounts to 295 roubles which surpasses wages in other branches of the national economy (217 roubles) by 36%.

The mean monthly wages include:

- tariff wage in accordance with the existing tariff system,
- bonus payments,
- extra payments connected with regional factors (for remote northern and eastern areas),
- payments for long time services,
- overtime payments,
- extra payments for work on holidays and for night-time work,
- payment for holidays and other leaves.

Under the Economic Reform, the methods of wage calculation have been changed. Now wages are determined as a part of the net income of an enterprise (difference between the volume of sale and material cost with depreciation).

Successful solution of the problem of labour supply for logging depends on the development of social infrastructure (housing, medical service, trade, etc.).

Power Supply in Logging

The electric energy consumption per one worker amounts to: (in th. kwhr)

- logging - 4.9,
- sawmilling - 12.7,
- chipboards - 62.8,
- fibre-boards - 67.0,
- plywood - 9.8,
- pulp and paper production - 101.9.

Theses values have increased on the whole by 48% for the last 10 years. The unit consumption of electrical energy in logging amounts to 4590 kwhr.

Current Cost in Logging.

There are as a matter of principal two different methods of logging cost classification:

a. working out cost estimates,
b. cost- price calculation.

The cost estimates include the following uniform economic elements:

- raw materials and direct materials,
- supplies (wire, oil, instruments),
- fuel and energy,
- direct and additional wages of the whole staff,
- charge for social insurance,
- stumpage price,
- depreciation charge,
- miscellaneous money expenses.

The distribution of expenses by the above mentioned elements is characterized as follows: (%)

- direct and additional wages - 48,
- depreciation - 20
- stumpage - 11,
- power cost - 12.

Costs of production for individual goods are determined by means of cost-price calculation. In this case, costs in logging industry are divided into the following cost items:

- direct and indirect wages of logging workers,
- charge for social insurance,
- equipment and roads maintenance cost,
- stumpage price,
- all-shop expenses,
- all-Factory expenses,
- commercial expenses,

The unit cost in logging (price-cost calculation) amounted to 17.9 roubles/m³ in 1988 and has doubled since 1968. The cost rise in logging has been caused by:

- wages growth,
- increase in sale prices for machinery,
- decline of forest stands (reduction of the tree volume, growing stock per ha, increase of the hauling distance, etc.).

At present, the rate of profitability of logging industry (i.e., a ratio of unit profit to cost) is low (3%). 20% of logging enterprises do not cover the current cost, their financial losses are subsidized by the State. The mean sale price of roundwood amounts to 18.50 roubles/m³. To eliminate State subsidies in logging in 1990, it is envisioned to raise the sale price of roundwood by 60% and increase stumpage prices by 80%

The Northern Forests - Main Ecological Characteristics

From the ecological point of view, the northern forests may be described as follows:

1. Low productivity of the forest stands due to the short growing season, low temperatures, extensive marshes and peatlands, and permafrost.

2. The mature and over-aged forest stands in the taiga zone are two-storeyed. The lower storey consists of young coniferous trees able to ensure proper regeneration only if the system of cuttings is changed. A system of selective cuttings needs to be introduced to replace concentrated clear cuttings. In this situation, there is a conflict between economic and ecological demands.

3. There are difficulties in using artificial forest regeneration (planting and seeding) due to poor soils, especially in the permafrost areas.

4. Over-aged forests are very susceptible to fire because of the high proportion of dead or damaged trees.

The Northern Forests - Goal Programmes

The ecological characteristics of the northern forest resources outlined above should be considered in the programmes for intensification of silvicultural activities to raise the ecological importance of the northern forests. The goal programmes should be based on the following measures:

1. Improving the methods of forest resources mensuration. It is envisioned:
   - to enlarge the network of the forest management and mensuration organizations;
   - to introduce on a large scale landscape-ecological methods of forest resource mensuration;
   - to extensively employ remote sensing techniques (satellite photography) to make regional forest cover maps.

2. Improving the final cuttings systems. The switch from clear cuttings to selective cuttings would make it possible:

   - to increase by 30% the output of roundwood per ha,
   - to significantly extend the harvesting period and thus create conditions for the constant supply of wood by integrated complexes,
   - to reduce the volume of forest planting by relying on proper natural regeneration,
   - to prevent the replacement of desirable coniferous tree species by undesirable deciduous tree species,
   - to extend the environmental protection functions which are partially lost due to clear cuttings. According to our calculations, the ecological benefits resulting from selective cuttings exceed the costs.

3. Expanding the forest regeneration activities. At present, the rates of forest regeneration are lagging behind when compared to the rates of cutting. Forest planting has covered only 15-20% of the area assigned for artificial regeneration. The difference between the area cut and the area planted, taking into account natural regeneration, amounts to 30-35%, being one of the causes of forest land loss. The increase in unproductive forest land area means that the environmental conservation functions of the forest are lost or lowered. This situation is particularly dangerous in mountainous and permafrost areas where the menace of soil and peatland erosion is very grave.

4. Expanding thinning programmes. Today, the area under thinning regimes amounts to only 7% of demand and only 0.7% of the forested area. Due to labour shortages in the forest workforce and the complete lack of demand for small- sized timber, it is envisioned that chemical methods should be developed for thinning young stands. This will, however, require constant ecological supervision.

5. Improving forest protection against fire and insects. In the northern forests, very high financial and ecological losses are caused by forest fires. In some regions, 10% of the growing stock has been destroyed and the quality of the stands has been reduced by 20-30%. The existing measures of forest fire control are applied only to forest areas under exploitation. Reserve forests are not protected against fires and insects.

TRENDS IN THE ECONOMIC, SOCIAL AND POLICY BASES FOR MANAGING MIXEDWOOD IN FINLAND

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ABSTRACT

Since the beginning of the 1960's, forestry and the forest industries have occupied a key position in promoting economic growth in Finland. As a result, the forest industries have expanded rapidly, with a simultaneous increase in forest improvement and management inputs. Despite the present pulping capacity, which is over 3.5 times as large as in 1950, the allowable cut is still estimated to afford a 15 per cent expansion of pulp output. The interplay between forestry, the forest industries and the national economy as a whole, has brought about an economic expansion with a feedback effect on the entire society. It has initiated a structural change in the more affluent society, with a consequent change in nonindustrial private forest ownership towards non-farm woodlots and new social values. In order to counteract the declining supply of roundwood and decreasing investments in forest improvements and management, new forest policy means are required. Economic theory suggests several possible policy means, but few of these will gain political consensus.

ECONOMIC GROWTH, FORESTRY AND THE FOREST INDUSTRIES

Finland is a country where the development of society as a whole is closely related to the interplay among forestry, the forest industries and the entire national economy. The benefits of this interplay were recognized at the beginning of the 1960's when a more conscious planning of the national economy proved necessary. Various alternatives for boosting the growth of the gross national product were explored. Owing to the dominatinag role of forests as a natural resource, investments for the expansion of the forest industries and a comprehensive intensification of timber growing turned out to be the most promising policy means for national economic growth.

An outcome of this expansive policy was that the pulping capacity was trebled during 1950-1970, while the expansion of the other primary forest industries was less drastic. At the same time, the consumption of industrial roundwood doubled. From 1970 to 1980 the processing capacity was increased by 20 per cent. The increasing need for industrial wood was supplied by transferring wood from other end uses, mainly fuelwood, by improving recovery and by increasing imports of raw wood. Removals from Finland's forests as such did not, however, increase.

This expansion of the forest industries would not have been possible without intensive forest improvement programmes, assuming a usual sustained yield. The timber growing investments amounted to a total cost of US$ 250 million annually (in real terms) in the 1970's and have since remained at the same level. This development has been induced by increased governmental intervention in private forestry through a combination of forestry legislation, cost sharing programmes and extension services. Consequently, as compared with the utilization of natural forests, capital intensity in forest resource management has increased. Even if actual achievements in certain types of forest improvement fell short of the set goals, the forest improvement output justified a considerable increase in the allowable cut.

These past periods were characterized by the expansion of the production potential in both forestry and the forest industries. However, the full utilization of these production potentials was not realized. Since the mid-

1960's the actual removals have remained below the allowable cut, 10 - 15 per cent on average. This is caused by a host of feedback effects following an increased affluence in urban society, which in turn had effects on timber sales and on investment behaviour of non-industrial private forest owners. Through increased costs and prices, these influences also extended to the demand for raw wood. It is understandable that less than full utilization of forest resources will result in losses in employment, in national product, in rural income and in export.

Apart from these trends, there is another main reason to reformulate our public forest policy on managing the forest resources. Today, we are again facing an expansion phase in the forest industries, planned on the basis of the prospects outlined in the Forest 2000 Programme. By the year 1995, the ongoing and planned expansions will further increase, e.g. the pulp output by about 15 per cent. The actual removals should increase at least 10, perhaps 17 million m^3. A vital question in forest policy is whether the forest owners are willing to increase their timber sales enough to shift the timber supply permanently to a level which supplies the additional raw wood requirement. Without policy intervention, many social and economic trends may endanger the achievement of the set goals for forest resource management.

CHANGES IN PRIVATE FOREST OWNERSHIP

The success of the forest policy is to a great extent dependent on the prevailing conditions in forest ownership and the changes in them. The following figures give a picture of the drastic structural change in private forest ownership and the predicted future outlook.

Table 1: Ownership structure in private forestry

	1971	1983	2000
	% of the number of owners		
Farmers	76	53	30
Non-farmers	24	47	70
	100	100	100
	% of the forest area		
Farmers	79	59	39
Non-farmers	21	41	61
	100	100	100

As compared with the traditional and rather stable forest ownership which was the majority of farmers, the new ownership group, i.e. non-farmers having an occupation other than farming, is very heterogenous in their social economic status and living conditions. Movever, the proportion of non-farmers is increasing rapidly and will soon become the majority.

The change in the main occupation of forest owners is only one feature revealing the ongoing structural change and social differentiation in private forestry, which will have effects on forest policy. The variation in the socio-economic background of forest owners has increased and resulted in diversified social values and goal setting in forest resource management. Most often, the changed forest management practice preferences are first encountered by the forestry professionals working in the field.

A trend that causes concern is the rapidly increasing number of those, most often absentee urban owners, who prefer other forestry benefits for efficient timber growing, such as recreation, amenity values and other intangible commodities. In the early 70's, 5 per cent and, in 1984, some 20 per cent of owners were in favour of the "green and soft values", while, in the year 2000 their proportion is predicted to amount to 40 per cent. In addition, practical administrative difficulties in communicating effectively with the forest owners are caused by the fact that one third of them live permanently outside the woodlot and, by the year 2000, 60 per cent are likely to be absentee owners. It is understandable that all the forestry organizations, local forest management associations, forestry boards and timber purchasing firms, face a new and challenging situation to adapt themselves to the new ownership structure with new values.

Thus, there does not exist a "typical and representative" forest owner any more who could be described by average statistics. Studies on forest owners have shown to be different in background and management behaviour. For example, studies on timber selling behaviour indicate that there is a group of forest owners who do not fell many trees, whereas there are also those whose cutting intensity is twenty times as much.

The present situation reveals two main possibilities for forest economic research and policy development: in spite of the intensified timber supply research the supply forecasts will become increasingly uncertain; the general, non-targeted policy measures may lose their effectiveness and, therefore, we are in need of more differentiated means to address different forest owner groups.

ECONOMIC TRENDS IN PRIVATE FORESTRY

Social conditions and economic basis are the other cornerstone in managing forest resources. The utilization of forest resources and investments in timber growing in private forestry are decisively dependent on the development of timber prices, stumpage earnings, costs of logging and silviculture and, hence, profitability. The main trends in economic development during the past decades have been favourable in that respect. To a certain extent, the economic situation has, however, changed in the late 1970's and during the 1980's.

Until the 1970's the increased demand for roundwood, together with rapid improvement in productivity (operational efficiency) in logging and especially in forest haulage have enabled an increase in stumpage prices. In real terms, the long-term average increase has been 1.5 per cent per annum. In the second half of the 1970's the growth levelled off and the real price level has been slightly declining since. This development is not due to unsatisfactory progress of productivity in logging and haulage; on the contrary, the operational efficiency in haulage trebled during the past ten years, while it improved by 50 per cent in logging. The costs of logging have remained at the same average level through the 1980s. The timber prices have followed the trends in export prices of forest products, there being a price agreement system between the interest organizations of the forest industries and forest owners. The world market prices have only recently allowed higher stumpage prices.

Likewise, the gross stumpage earnings of private owners have followed an increasing trend until the late 1970s, when the growth discontinued. During this decade stumpage earnings have, in real terms, amounted to US$ 25 billion on average.

The costs of silviculture show an upward trend. The real costs of artificial regeneration (planting) especially have risen rapidly, while the upward cost trend in other silvicultural activities like seeding and stand improvement has been less pronounced. Higher regeneration costs have, however, been partly compensated for by tax relief granted to properly managed regeneration areas.

As a result of the above trends, the business economic profitability of private forest management has slightly decreased. Moreover, the ongoing general tax reform in Finland is likely to add to the pressure of increasing the tax revenues from private forestry and, thus, further impair the financial yield to forest owners. Furthermore, due to moderate inflation and the developments in money and capital markets, the opportunity cost of timber growing has increased and, thus, forestry is likely to lose its earlier attraction as an investment alternative. The unifying Europe will put further pressures on forestry in terms of profitability and competitiveness.

A reason for both optimism and concern is brought about by the expected expansion of the wood processing capacity of the forest industries. As such, it will increase demand for raw wood from private forest and, hence, contribute to profitable forest management. On the other hand, if profitable timber growing as compared with other alternatives in the economy is not guaranteed in the long term, the domestic wood availability may endanger the expansion of the forest industry firms.

There are two main avenues to raise the profitability: in the short term, one can affect the timber supply to increase the cuttings to the level which the forecasts at present allow; and, in the long term, to raise the operational efficiency both in logging and haulage, and especially in silviculture. It means increased mechanization, substitution of capital for the increasingly expensive labour. This is also the prospect in Finland in the 1990's.

However, there are obvious trends threatening this desirable development: increased fragmentation of private woodlots which reduces the economies of scale in forest management and adds to "the soft and green values" among forest owners and the general public. In addition, we are likely to face a rising cost level because the additional removals should increasingly result from thinnings.

In silviculture, we are left with an alternative which deserves serious consideration: to favour natural regeneration where possible more than at present, where it is biologically feasible. In practice, we can then favour mixedwood management by combining artificial and natural regeneration.

NEED FOR A REFORMULATION OF PUBLIC POLICIES

The rather small Finnish open economy, which is dependent on international trade and exchange, is sensitive to fluctuations in the international economy. In order to maintain both the external and internal balance of her economy, Finland has to employ active measures of public economic policy. Given the dominating role of forestry and the forest industries in the national economy, the general economic policy affects the production in forestry and the wood economy. In the present situation with the

expected expansion of production capacity in the forest industries in Finland, the balanced growth would presuppose that the general economic policy and public forest policy could find a parallel course. A high inflation rate with a simultaneous increased wood demand might induce an imbalance in the timber market.

The success in enhancing the growing stock and the allowable cut can partly be ascribed to the forest policy measures designed to stimulate the timber growing investments during the past decades. Through a combination of forestry legislation (Private Forestry Law, Forest Improvement Law, Law on Forest Administration, Law on Forestry Boards), state subsidies (grants and loans, tax exemptions) and overall promotion of private forestry (technical assistance, extension services for and education of forest owners) the private forest owners have been induced to invest in silviculture and forest improvement.

As described above, the production possibilities have not been fully utilized. Thus, the forest policy issues focus has clearly shifted from investment stimulation to the timber markets. If the planned investments in the wood processing capacity, in accordance with the removal targets expressed in the Forest 2000 Programme, are to be realized, the key issue in forest policy in the 1990's will be the timber supply from non-industrial private forests. This has also been recognized by intensifying research into the timber supply and the effectiveness of forest policy means.

What would then be the remedies to be recommended to shift the supply to the level the forest industries would require if the social and economic trends suggest a less desirable future? Economic theory might suggest a variety of possible means, but only a few may gain political consensus and be feasible. The Forest 2000 Programme provides three main policy domains to affect the timber supply: timber trade policy, general economic (fiscal and monetary) policy, and the forest policy proper.

A basic starting point in designing a forest policy programme promoting the timber supply is to explore to what extent the market forces, i.e. increased demand and, thus, a higher timber price, will affect the timber supply of private forest owners. Econometric research into the supply behaviour has given evidence of a rather inelastic timber supply, at least in the long term. In the short term, the price expectations caused by the price fluctuations, will counteract the positive stimulus of increased stumpage prices, resulting in smaller quantities of timber exchanged in the market than expected. This has also been recognized in the timber trade policy by attempting a smooth and moderate price development. In general, timber trade policy including agreements on recommended prices has been considered to have a positive influence on timber markets. The price ratio between sawlog and pulpwood is a means in guiding the composition of cuttings. The price differences have in that respect somewhat narrowed down recently.

The cuttings from private forests have their economic motives in the investment and consumption behaviour of forest owners. Thus, measures taken in money and credit markets or in fiscal policy will also have an effect on timber supply. The experience in Finland has indicated that a high inflation rate with a low real interest is a disincentive to cuttings; and, conversely, we may contribute to timber supply by low inflation and rather tight credit and interest rate policy. The substitution of borrowing for stumpage income as a means of financing then declines.

There are two main aspects associated with forest taxation: fiscal and forest policy. In Finland we employ an area-based yield taxation system in forestry which enables certain tax exemptions and reliefs on certain timber growing investments. The tax levied is independent of actual stumpage revenues. During the past ten years, the assessed taxable revenue has been, on average, 75 percent of the gross stumpage earnings. As such, the taxation system has been considered quite neutral as regards its impact on timber supply. In the long run, it has had an obvious positive influence on timber growing.

Recently, two issues on forest taxation have been discussed. First, the general tax reform is likely to expand the tax base also within forestry and, thus, to increase the taxable revenue. This fiscal aspect, however, has a counterpart in forest policy: What effects has the increased tax burden, for example on timber growing investments? Second, discussion has been initiated on whether the shift to the taxation of actual stumpage revenue would be a better alternative for forest owners. It is obvious that in the present situation it might lead to a decreased timber supply and, thus, endanger the planned expansion of the forest industries.

However, from the forest policy point of view a more defensible course has now been adopted: the government's proposal for the budget for 1990 contains a proposal on tax relief on first thinnings. Moreover, tax incentives for forest regeneration have been suggested to be tied more closely than before with the cutting decision taken by the forest owner. In short, the tax burden will shift slightly to old and mature stands, which is likely to give motivation to carry out final cuttings. All these means are in line with the tendency to shift the emphasis of forest policy in order to increase cuttings.

Among the forest policy means proper, the Forest 2000 Programme gives considerable weight to the intensification of forest management planning, combined with personal consultation with forest owners. To increase the effectiveness of management planning, development work is in preparation to improve the plans in order to achieve better than before the economic aims which forest owners set on their forest management. More generally, all the forest promotion measures, such as planning, training and services, are to be differentiated to meet the diversified needs and goals of different ownership categories. Both the channels used in communication and the technical contents of consultation have to be tailored to fit each forest owner segment.

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FINLAND: FOREST MANAGEMENT IN A CHANGING ENVIRONMENT

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ABSTRACT

Finland's forest resources have increased down the years. Since a substantial amount of the cutting potential has been left unutilized and the availability of raw material for the expanding wood-based industry may become a problem, the whole forestry programme was recently updated. Among various measures for its implementation, an important role is expected to be played by management plans in small-sized private ownership. As regards deciduous trees, the consumption of birch wood by the Finnish pulp and paper industries has increased in recent decades. This makes conditions favourable for growing deciduous trees, not to mention the variety they add to the landscape, their ecological effects and the yield. Silvicultural systems need be developed further to utilize deciduous tree growing in either pure or mixed stands.

DATA ON FINNISH FORESTS AND FORESTRY

Here, to start with, are a few figures with a bearing on Finnish forestry. Finland's population (5 million) amounts to 0.1% of the world total. It's share of other world totals is as follows (Key 1988):

Forests	0.5%
Coniferous forests	1.0%
Drain	1.5%
Fellings of industrial roundwood	2.5%
Production of forest industries	5.0%
Exports of forest industry products	10-15%
Exports of printing and writing paper	25%

The share of wood-based products in Finland's export earnings is as much as 36% of gross exports, and they account for over half of its net export revenue. These figures are of major economic importance to a country that has no oil or coal resources, and whose mineral reserves are limited.

Finland's forestry and wood-based industries directly employ 80,000 to 100,000 people, i.e. almost a fifth of the Finnish labour force. If the indirect effects on employment are counted as well as the direct effect, forest industries provide employment for more than 200,000 Finns in towns and country alike.

Two-thirds of Finland's land area is covered by forests whose total area is 20 million hectares with growing stock of 1800 million m^3. These forests are mainly in private, non-industrial ownership: 63% of them belong to holdings with an average size of only 30 hectares. The State owns 24%, companies 9% and local authorities and parishes 4% of the area.

The main tree species in Finland are Scots pine, (*Pinus silvestris*), (45% of the volume), Norway spruce (*Picea exelsa*) (37%), and two species of birch (*Betula sp.*) (15%). The remaining 3% is divided between alder and aspen. I'll return to the question of species later in this paper.

Finland's forest resources, like those of its neighbours Sweden and Norway, have increased down the years. This is clearly shown by the results of the national forest inventories made regularly since 1921. The 8th National Forest Inventory is now under way. Surveys of wood utilization, made in parallel with the inventories of growing stock, give a reliable picture of the forest balance. Special importance is attached to regular repetition of these investigations: they have made it possible to follow and even foresee the trends in Finnish forests, and thus guide development in the direction desired.

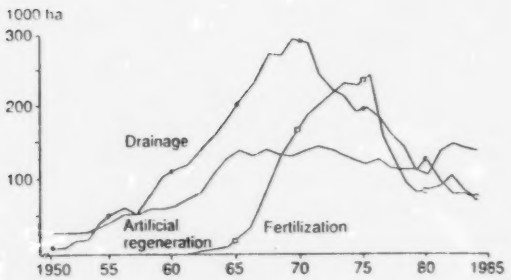

Figure 1. Forest improvement and artificial regeneration

The progress depicted above has been achieved through improvements in forest management. Selective cuttings to a diameter limit have largely been abandoned. Other important measures that have increased timber production have been forest drainage, artificial regeneration and fertilization (Figure 1; Yearbook...1987). The driving force behind these measures has been the development programmes drawn up in the 1960's which were funded by the Forest Fund Programmes (MERA), and partly, too, by a loan from the World Bank. But forest owners themselves have always played the decisive role.

Peat bogs were already drained on a considerable scale in the '20's and '30's. The 300,000 hectares drained in 1969 represented the peak of drainage during the MERA period. The present total area of drained peatland is well over 5 million hectares. Some 100,000 ha of forest have been fertilized annually during the '80's. Artificial regeneration became an important method of reforestation in the '50's. During the past 40 years a total of 7 million ha of forest have been regenerated - more than a half by planting or seeding.

UPDATING THE FORESTRY PROGRAMME

Consolidation of the growing stock has increased the sustainable cutting potential. In the early '80's this increase was estimated to have been clearly greater than 10 million m³ annually since the mid-50's, and it has obviously created a favourable environment for the expansion of the forest industries. The consumption of wood by industry more than doubled during this period (Figure 2).

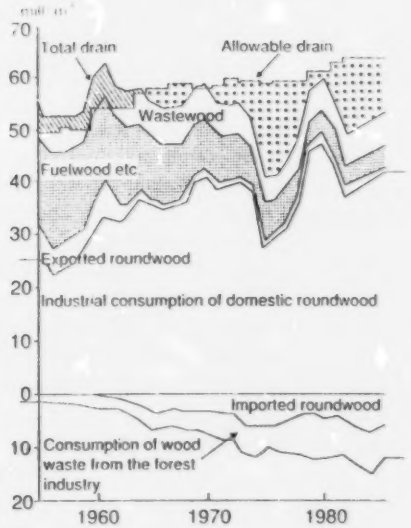

Figure 2. Forest balance

This increase was also made possible by the fact that at the same time there was a considerable decrease in the consumption of wood for fuel and in exports of roundwood, and an increase of wood imports. The overall trend in total amounts of wood harvested has been downwards. A growth in the actual cutting potential has thus been left unutilized at the same time as the wood-based industries have experienced difficulty in procuring sufficient raw material.

In Finland, even small disturbances in the development of forest industries can weaken the balance of payments. Stable progress in these industries is a precondition for steady development of the national economy as a whole.

Under these circumstances it was decided to perform a study embracing the whole of the forestry sector in Finland. In February 1983, the Economic Council set up a Forest 2000 Programme Subcommittee to draw up a long-term programme for forestry and the forest industries in Finland. In addition to a steering group and working committee, working groups comprising experts from four

different fields were named to plan forest management and silviculture, the multiple-use of forests, timber procurement, and development of the forest industries. All this has stimulated forestry research in Finland. The overall Programme also included a special programme for development of forestry research. The original Forest 2000 Programme was finalized early in 1985.

The programme has been well-received on the whole, and the Finnish government has paid due attention to it in preparing the national budgets. Its implementation is also being monitored continuously.

The timber production targets of the Programme envisage a 25% (12 million m³) increase of the annual cut over the 1980 level by the year 2000. This goal presupposes a more effective utilization of the cutting potential than during the '70's and '80's. By the end of the century the cutting area will have to be enlarged by almost a third. The greatest expansion, 70% will have to occur in the area thinned annually. This means that the proportion of natural regeneration will have to be increased considerably in reforestation, though artificial regeneration will continue to be important. There will be a slight shift in emphasis from planting to seeding. Pruning of standing trees will increase.

Major changes are planned in basic improvements. All the new drainage operations are due for completion in the '90's. In addition redrainage, which includes ditch cleaning and supplementary ditching, will grow three-fold by 2000. Forest fertilization will be doubled. If the Programme's targets can be met as proposed, the volume and annual increment of the growing stock will increase still further.

In drawing up the Timber Production Programme, more attention has been paid to the multiple use of forests. Raising the production of timber depends to a great extent on integrating it with other forms of forest use. Forest berry and wild fungi picking supplement timber production, and the berry crop can be utilized more effectively. Neither do game management or reindeer husbandry conflict with timber production to any marked degree. The value of other forest products compared to that of timber averages 10% in the whole of Finland, and 25% in the northern province of Lapland.

The recreational use of forests is fairly easy to integrate with timber production. Forest land set aside for conservation and recreational purposes totals 1.7 million ha in Finland. This area is not likely to be increased very much by the year 2000. It is estimated that multiple use will reduce the annual cutting potential by 2.2 million m³, i.e. by 3-4%.

PROBLEMS IN IMPLEMENTING THE PROGRAMME

The good management and silviculture practised during past decades has substantially increased the cutting potential in Finnish forests. Thanks to this, and to the good market for forest products in recent years, Finland's forest industries are rapidly expanding. Annual investments are expected to exceed US$ 2 billion for many years to come. The expansion will apply mainly to paper and paper board. On the whole, the trend in the raw-wood demand corresponds fairly well to the cutting targets of the Forest 2000 Programme. There is only one major exception: it is likely that some 8 million m³ of saw-timber sized trees will have to be used for fibre production. For instance, 40% of spruce saw-logs should go to pulp mills.

With these favourable prospects in mind, one may wonder if there are still any obstacles to progress. One factor requiring attention is the availability of raw material.

As mentioned above, a substantial amount of the cutting potential has been left unutilized since 1970, and the new goals presuppose a more effective utilization of this potential. We therefore need to be aware of the main reasons for this reluctance to fell adequate quantities of timber from Finnish forests.

The first point to be borne in mind is the structure of forest holding ownership in Finland. Seeing that 80% or so of the volume of timber supplied to the wood-processing industry has to be obtained from private forests, which average 30 ha in size and number almost 300,000, the importance of this form of ownership is decisive. There are many reasons for the hesitation to cut timber in these woodlots. Major changes have occurred in forest ownership during recent decades. More than a third of forest owners nowadays live away from their holdings. Their income and wealth have increased, and their dependence on revenue from their forest holdings has decreased.

Furthermore, the size of the annual cut is at the discretion of the forest owner. The most important stipulation in the Forest Act is that "The forest shall not be devastated.", and the act specifies that prudent regeneration and growing measures be employed to ensure this. But it does not prescribe cuttings of any particular volume.

Secondly, certain measures in forest management - particularly forest drainage and large-scale regeneration cuttings and site preparation - cause temporary changes in the landscape, so they have come in for considerable criticism and have discouraged some of the forest owners from cutting.

Another cause of uncertainty is the threat posed by air pollution, the effects of which are hard to evaluate. The impact of air pollutants on forest ecosystems has attracted much attention, especially in continental Europe, where damage has occurred particularly in mountain forests. Two-thirds of the pollution load in Finland originates from foreign sources. The current situation is being evaluated by a systematic and multidisciplinary survey based on the network of permanent sample plots used in the national forest inventory. Damage trends will be determined with repeated measurements. Other research is being conducted on the mechanisms of forest damage, and possibilities of preventing and alleviating such damage by silvicultural measures.

Air pollution damage in Finland so far appears to be mainly local, and acid deposition is not likely to affect cutting volumes and forest management to any marked degree in the near future.

It is quite obvious that countermeasures are needed to overcome these causes of uncertainty among forest owners that are reducing the quantities cut. In particular, the role of management plans is becoming important. The regularity and intensity of management and cuttings made in private forests have been found to depend largely on how well the forest owners know their forests.

An effective way to increase the owner's knowledge of their forests, and thus make fuller use of the cutting potential, is to draw up forest management plans. This activity involves the various forms of consultation. Considerable efforts have been made in Finland since the early '70's to increase the use of management plans. A coverage of 90% is the target for the first half of the '90's. It should be noted, however, that even if there are not written plans, technical advice needs to be continuously available for all forest owners through their forest management associations.

THE ROLE OF MIXED WOOD

The theme of this symposium is Mixed Wood. I understand that, until recently, British Columbia's commercial forests were limited to coniferous species, but that certain deciduous species have been found to have commercial value. "A management strategy must be developed to strike a proper balance between coniferous and deciduous resource, and this strategy must take into account economic as well as biological factors" (NILS 1989).

So it may be of interest to you to consider the role of deciduous trees in Finnish forestry, though your deciduous trees include various aspen (*Populus*) species, whereas Finnish commercial forests contain two species of birch (*Betula*).

In recent decades a clear change has occurred in the part played by deciduous trees in Finnish forestry. In the '50's and early '60's they were still a problem for Finnish silviculture, because there was only a minor market for small-sized birch as industrial wood. Now, in the '80's, the situation has changed completely: birch has become a highly sought-after species for industrial pulp wood. This change will be clear from the following percentages depicting the industrial consumption of domestic roundwood:

	Pine	Spruce	Deciduous	Total
		(%)		million m³
1960	44	49	7	31.4
1985	44	40	16	41.5

Pulp wood accounts for most of the increase of deciduous-tree cuts from 2.3 to 6.7 million m³. Furthermore, 42% of the total 5.5 million m³ imports of industrial roundwood in 1985 were deciduous species, almost all of them pulp wood. The consumption of deciduous wood by the Finnish pulp and paper industries has thus increased substantially. This makes conditions favourable for growing deciduous trees in Finland, not to mention the variety they add to the landscape. Birch does not grow in pure stands, but it is more often mixed in stands dominated by Scots pine or Norway spruce. At all events, mixed-wood management is a highly topical theme in Finland.

Studies on the ecological effects of deciduous trees indicate that decomposition of their litter improves soil properties. The high calcium content of birch leaves stimulates microbe activity and speeds up the circulation of nutrients in the soil (Mikola 1985). The highest pH in the upper layer of the soil has been noted in stands with a large proportion of birch (Troedsson 1985). In other studies, too, mixed stands are found to have been healthier than monocultures (e.g. Rennerfelt 1946), and the microclimate of a mixed stand is unfavourable to a certain genus of harmful insects (Ozols 1960).

Much research has been made in Northern Europe on yields from mixed birch and conifer stands. Earlier studies showed that a birch mixture improves the diameter and

height growth of conifers (Lappi-Seppala 1930, Jonsson 1962). It has also been demonstrated that Norway spruce stands with a birch shelter produce more wood than pure spruce stands do (Tham 1988). Finnish investigations have indicated that birch usually increases the total yield of mixed birch and spruce stands in terms of dry weight (Mielikainen 1985).

An economic analysis shows that under certain conditions mixed stands are economically superior to pure stands, the optimum birch percentage being 20-60% (Valsta 1988).

Basing on positive research findings and practical experience, silvicultural systems have been developed to utilize deciduous trees growing in either pure or mixed stands. Naturally, considerably more research is needed to improve mixed-wood management.

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CURRENT AND FUTURE TRENDS IN HARVESTING, UTILIZATION AND PROCESSING OF MIXEDWOOD IN FINLAND

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Finland is a typically open economy with increasing dependence on the international market. As late as the early 1960's, a good third of industrial production was exported; today the proportion is 55%. A quarter of a century ago imported goods accounted for a mere 18% of the final domestic demand for manufactured products; today the figure is about 50% (Figure 1).

FINLAND'S EXPORTS DIVERSIFIED

Total exports at fixed prices have increased by 5.4% per year since the early 1960's: thus the value of exports has quadrupled in 25 years. The proportion of Finland's total exports accounted for by the forest industry has, in that time, been reduced from 69% to 37%. However, by the mid-1980's, the real value of forest industry exports had doubled the level of the early 1960's.

The metal industry has been the most powerful growth factor in exports, for its share of total exports has gone up from 10% in 1960 to the current 38%. Diversification in the structure of industrial production is partly based on know-how in wood processing. In the course of the years, an extensive industrial sector manufacturing paper mills and machinery for forestry has emerged in Finland. The country's expertise in building icebreakers is largely the result of a need to secure year-round deliveries in the export industry.

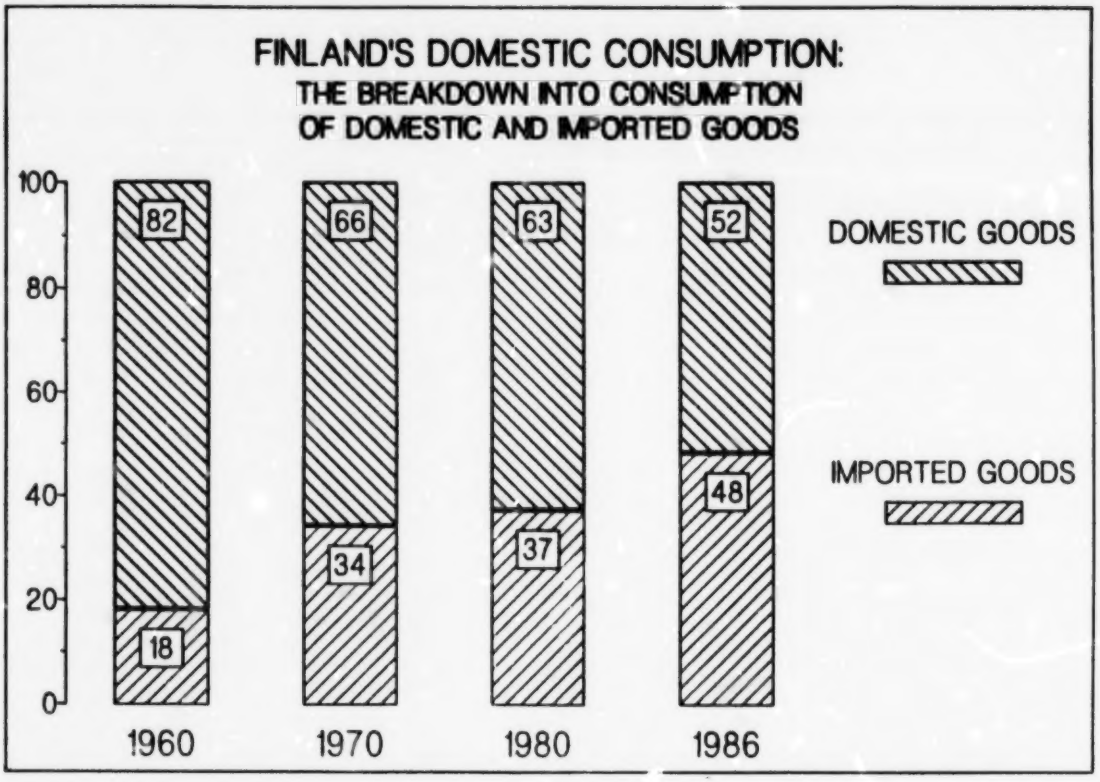
FOREST INDUSTRY - EXPORT INDUSTRY

A good 80% of the paper and paperboard industry's production is exported. The proportion accounted for by board has been declining slightly, which is due to the growth in domestic processing; there is a tendency to export an increasing proportion of the production as converted products.

The proportion of exports accounted for by wood pulp has also been declining. In the 1960's, market pulp still accounted for 46% of sulphate pulp production, but in the 1980's the figure has come down to a good 30%. This means that both production and exports by the paper and paperboard industry using pulp as raw material have increased substantially. The principle behind this trend is clearly a desire towards more value-added production.

Birch-faced plywood and coniferous sawnwood are the major Finnish export articles in the mechanical forest industry. A good 85% of plywood production and close on 65% of coniferous sawnwood are exported. The contribution of particle board and fibreboard to exports is declining, since they are typical standard products not sufficiently competitive on the export market; consumption of these products is increasingly shifting towards the home market.

In the 1980's, 39% of particle board production and 48% of fibreboard production have been exported (Table 1).


FINLAND'S DOMESTIC CONSUMPTION:
THE BREAKDOWN INTO CONSUMPTION
OF DOMESTIC AND IMPORTED GOODS
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DOMESTIC GOODS
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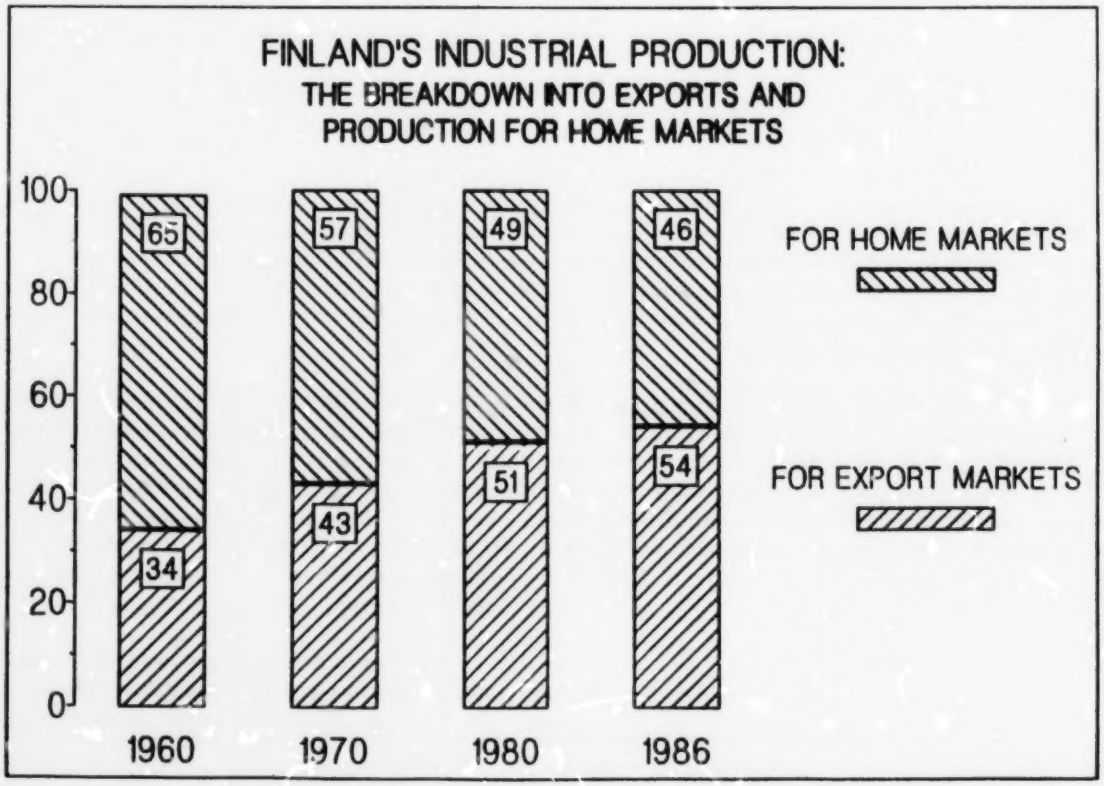
FINLAND'S INDUSTRIAL PRODUCTION:
THE BREAKDOWN INTO EXPORTS AND
PRODUCTION FOR HOME MARKETS
100
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1960
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FOR HOME MARKETS
FOR EXPORT MARKETS

Figure 1.

TABLE 1. The share of exports in Finland's forest industry production, 1960-1986. (*)

	1960-70	1970-80	1980-86
		%	
Coniferous sawnwood	64,1	65,0	64,3
Plywood	84,8	84,6	85,8
Particle board	38,0	43,5	38,5
Fibreboard	66,5	55,1	48,6
Wood pulp	38,8	24,6	21,4
• mechanical	9,2	1,4	0,9
• chemical	49,9	35,2	32,6
Paper	82,6	82,0	82,9
Paperboard	83,5	79,7	78,2

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).

FINLAND'S EXPORT MARKET IN EUROPE

Europe is the most important marketing area for Finland's forest industry. The proportion of total exports accounted for by the EC (12) was some 60% in the mid-80s, and the proportion accounted for by the whole of Western Europe some 69%. The UK alone accounts for a fifth of Finland's total forest industry exports.

The plywood market is clearly anchored in Western Europe. Exports by the sawmill industry are concentrated on the EC area in particular. The largest market area for converted paper and board products comprises the Comecon countries, the Soviet Union in particular. The export market for paper products is considerably more extensive than that for the other product lines (Table 2).

GROWTH MOST POWERFUL IN THE PULP AND PAPER INDUSTRY

Production by the mechanical forest industry has not grown significantly since the early 1960's. The fibreboard industry expanded vigorously in the 1960's, but production in that sector has declined by the 1980's. The sawmill industry has increased its production only very slightly (Table 3).

Pulp industry production has steadily increased since the early 1960's. Production of mechanical pulp has nearly tripled, whereas that of chemical pulp has doubled. Production of semichemical pulp began, in its current scale, in the 1960's. The production of sulphite pulp has decreased dramatically, as the production of sulphate pulp has increased to a level three times higher than at the start of the 1960's (Table 4).

The paperboard industry grew rapidly in the 1960's and is continuing to expand its production in the 1980's. The growth in paper production has also been very strong,

TABLE 2. Finland's forest industry exports by region, 1985-1987.

	Conif. sawnwood	Plywood	Wood pulp	Paper	Paper-board	Converted pap&board products	Total forest industry
				%			
Europe	79,3	90,7	84,3	74,5	80,9	93,7	81,2
- EEC	73,2	60,7	65,6	61,4	65,3	38,2	60,2
- EFTA	5,0	25,6	5,9	5,3	5,9	16,2	8,3
- CMEA	0,7	4,2	11,8	7,7	9,4	39,2	12,5
Asia	5,2	3,1	9,8	8,5	11,2	2,4	6,8
Africa	15,3	1,6	2,5	1,6	3,3	1,2	3,2
North America	0,0	4,5	1,1	10,3	1,4	1,8	5,7
Latin America	0,0	0,0	0,1	2,4	1,3	0,2	1,2
Oceania	0,1	0,0	2,2	2,8	2,0	0,6	1,9

TABLE 3. Production by Finland's mechanical forest industry, 1960-86. (*)

Year	Conif. sawnwood m^3	Plywood m^3	Particle board m^3	Fibre-board t
			1000	
1960	6866	378	79	184
1970	7087	677	428	241
1980	8610	605	725	152
1986	7592	592	592	106
Period			**Growth, %/yr**	
1960-70	0,3	6,0	18,4	2,7
1970-80	2,0	-1,1	5,4	-4,5
1980-86	-2,1	-0,4	-3,3	-5,8

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).

TABLE 4. Production by Finland's wood pulp industry,1960-1986. (*)

Year	Mechanical	Semi-chemical	sulphite	Chemical sulphate	Total
			1000 t/yr		
1960	988	68	1221	1266	3543
1970	1701	319	1370	2672	6062
1980	2276	297	730	3585	6888
1986	3016	325	402	4517	8281
Period			**Growth, %/yr**		
1960-70	5,6	16,7	1,2	7,8	5,5
1970-80	3,0	-0,7	-6,1	3,0	1,3
1980-86	4,8	2,5	-9,5	3,9	3,1

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).

TABLE 5. Production by Finland's paper and paperboard industry, 1960-1986. (*)

Year	News-print	Printing & writing paper	Kraft-paper	Other paper	Total paper	Paper-board	TOTAL
				1000 t/yr			
1960	798	238	287	125	1449	579	2028
1970	1299	919	468	309	2995	1272	4267
1980	1502	1995	535	285	4317	1448	5765
1986	1715	3513	568	300	6054	1663	7796
Period				**Growth, %/yr**			
1960-70	5,0	14,5	5,0	9,4	7,5	8,2	7,7
1970-80	1,5	8,1	1,3	-0,8	3,7	1,3	3,1
1980-86	1,8	9,9	1,0	0,8	5,8	3,1	5,2

(*)Figures in all tables are based on five-year floating averages (1960:1958-62).

particularly on the part of printing and writing paper. Growth in this product group has been over 10% annually (Table 5).

With reason, it can be said that Finland's forest industry focuses on those products and product groups which are best suited to domestic raw materials and to the country's technical and marketing know-how. This is evidenced by the following figures:

Finland's share of global

forest resources	0.5%
coniferous forest	1.0%
total removals	1.5%
removals of industrial roundwood	2.5%
forest industry production	5.0%
forest industry exports	15.0%
printing and writing paper exports	25.0%

INCREASE IN FOREST INDUSTRY'S MARKET SHARES

The Finnish forest industry's success in exporting can be measured by examining its share of the market. Since the mid-60s, Finland's production of coniferous sawnwood has remained at about 10% of Europe's coniferous sawnwood consumption. The recession following what has come to be known as the first oil crisis was clearly reflected in the sawmill industry's loss of competitiveness in the mid-1970's. 1980 was a record year for the sawmill industry, with production rising to over 10 million m^3, and the share of the market going up to nearly 13%. The plywood industry lost ground in the 1970's, but through specialization has managed to improve its share of the market to about 12% (Figure 2).

The share of European paper and paperboard consumption accounted for by Finnish paper and paperboard production has risen from its level of a good 10% in the mid-1960's to its current level of nearly 15%. This increase has been a consequence of the favourable market trends for printing and writing paper; during the same period, the market share accounted for by these products has risen

Figure 2.

Figure 3.

from 7% to nearly 20%. The trends for the market share of newsprint indicate a particularly large cyclical fluctuation of between 26 and 16% (Figure 3). It should be pointed out, however, that in the mid-1980's as much as 25% of Finland's entire paper production was exported to countries outside Europe.

USE OF PULPWOOD INCREASED

Owing to developments in production, growth has been greatest in the use of wood by the pulp industry. Since the early 1960's, the use of wood raw materials has increased by around 3% annually. The use of spruce as a raw material for pulp production has not increased; the decreased use of spruce in the production of sulphite pulp has been offset by the increased use of this type of wood in mechanical pulp production. Of the various types of wood used in pulp production, the largest increase has taken place in the use of birch. As a proportion of the round wood used, birch now amounts to nearly one third, up from the few per cent which it accounted for in the early 1960's.

Wood imports have become an essential source of raw material for the pulp industry. In the mid-1980's, imports accounted for as much as 17% of the wood used annually by the industry, the Soviet Union being the largest supplier.

The use of domestic wood residues, mainly chips and sawdust from the sawmill and plywood industry have increased significantly in the pulp industry, rising from less than 2 million cubic metres in the early 1960's to the current 6.5 million cubic metres (Table 6).

Although industry's use of wood has increased one and a half fold since the early 1960's, the total annual drain on Finland's forests has diminished somewhat. This has been a consequence mainly of the decrease in the use of fuel wood and in the level of wood exports, which has not been offset by the increased use of wood raw materials by the industry.

Since the possibilities for cutting at a sustained yield have improved in Finland as a result of good silviculture and forest management, the Finnish forestry has undergone a transition from the period of overcutting in the early 1960's to the current period of underexploitation of forest resources. In the mid-1980's, nearly one fifth of annual forest growth was being left unused (Table 7).

TABLE 6. Wood raw material consumption by Finland's wood pulp industry, 1960-1985. (*)

Year	Domestic roundwood				Domestic wood residues	Imported wood	Total
	Pine	Spruce	Birch	Total			
	Mill. m³/yr						
1960	4,70	8,98	0,69	14,37	1,80	0,17	16,36
1970	6,43	10,59	3,57	20,60	3,80	2,54	26,94
1980	7,30	8,90	4,01	20,21	6,39	3,50	30,10
1985	8,05	8,55	4,80	21,39	6,55	5,76	33,70
Period	Growth, %/yr						
1960-70	3,2	1,7	17,9	3,7	7,8	..	5,1
1970-80	1,3	-1,7	1,2	-0,2	5,3	3,2	1,1
1980-85	2,0	-0,8	3,6	1,1	0,5	9,5	2,3

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).

TABLE 7. Total drain, allowable drain and forest balance, 1960-1985. (*)

Year	Total drain	Allowable drain	Forest balance			
			Pine	Spruce	Non-conif.	Total
	Mill. m³/yr					
1960	57,9	52,9	-2,1	-2,3	0,4	-5,0
1970	56,0	58,6	-0,1	3,9	-1,3	2,6
1980	53,7	61,5	-0,1	3,6	5,1	7,8
1985	52,1	65,9	2,4	5,3	6,5	13,8
Period	Growth, %/yr					
1960-70	-0,3	1,3	..	..	..	..
1970-80	-0,4	0,5	..	..	..	..
1980-85	-0,6	1,4	..	..	..	..

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).

EXACTING LOGGING CONDITIONS

The predominance of small-scale private ownership strongly influences the way in which the Finnish forests are managed and utilized. The average woodland area of a private forest owner is 35 ha, and the average sale consists of only 340 m3 of timber. These facts constrain mechanization and increase logging costs.

In addition to the 40 million m^3 of timber cut annually from the private forests, another 10 million m^3 is harvested in large-scale operations from state- and company-owned forests. Therefor, machinery and methods have been developed for both types of operations.

Majority of forests lies below an altitude of 200 m. Logging never takes place in real mountain conditions. Therefor, cable logging systems are not used.

The terrain is characterized of small hills. The slopes, seldom steeper than 20-30%, are trafficable with forest tractors. However, the soil is often stony and covered with boulders, or in flat terrain soft and swampy. This sets high requirements for the machinery and operational planning in off-road haulage. In the winter time the peat-lands freeze and the snow cover levels the ground surface.

One of the most important factors affecting the productivity and cost of logging is the size of the trees. Due to the climate the trees are relatively small in Finland. The average stem volume of harvestable trees is about 0.2 m^3 for Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*), and 0.1 m^3 for birch (*Betula pendula and B. pubescens*).

REPEATED THINNINGS - THE BASE IN LOGGING SCHEDULE

The principles of forest management and exploitation in Finland are aimed not only to increase the yield but also to improve the species composition and quality of the timber.

Finnish cutting systems are characterized by repeated selective thinnings from below. The present thinning practice was accepted in Finland several decades ago as soon as the development of the pulp industries guaranteed markets for small-sized timber. Nearly all stands in southern Finland are thinned selectively from below twice or three times during the rotation of 70-90 years. As a result of tree size, the cost of logging is highest in the early thinnings and lowest in the final cuttings:

Treatment	Approximate age, years	Relative cost of logging
Precommercial thinning	10-15	
1st commercial thining	25-35	300
2nd commercial thinning	40-50	200
3rd commercial thinning	55-65	150
Final cutting	70-90	100

The results of the repeated thinnigs can be seen everywhere in Finland: a favourable development in the structure of the forests, decreased natural loss, decreased amount of decay-defected timber, decreased amount of logging residue, improved species composition, and increased average tree size.

Compared with clear-cuttings, in the thinnings productivity of work is lower and mechanization much more complicated.

Consequently, the logging costs are higher and the stumpage prices lower. For these reasons it is presently not possible to reach the thinning targets of the national management programs, like Forest 2000, in the full scale. Less than 30% of all timber is harvested from thinnings presently.

INFRASTRUCTURE FOR TIMBER HARVESTING

The forest industry companies purchase two thirds of their timber standing. One third of the total annual cut is delivered to the road side by self-employed forest owners.

No matter what sale type is used, the forest industry companies buy the raw material through their own woodland divisions. The companies are thus responsible for most of the logging operations.

A majority of Finland's 24 000 forest workers are employed by the companies on a permanent basis. In addition to logging, the same workers take part in silvicultural operations such as planting and tending. About 400 forest workers complete a two-year forest workers' vocational programme annually.

The workers are paid by piece rate. The average daily earning of a worker using his own power saw is roughly 300 FIM or US$ 70. In addition, the employer has to pay another 150 FIM per day for social security, vacations, insurance, travel expences etc.

The forest tractors, multi-purpose machines and timber trucks are owned by private contractors. Most of them have

a permanent contract with a timber company guaranteeing a certain minimum amount of work per year or a certain minimum annual earning. There were more than 2000 forwarders and 1000 multi-purpose machines in Finland at the end of 1988. Almost 300 forest machine drivers complete a two-year training program annually.

The state supports forest road construction in private forests with low-interest loans and free planning. The annual work result in the whole country exceeds 4000 km new permanent forest roads. The program has been successful in decreasing the average off-road haulage distance in southern Finland to some 300-350 m.

The long-distance transport always starts with a truck, generally equipped with full trailer, but it often continues with railway or floating. In 1987 as much as 26% of the total performance in the long-distance transport (timber volume multiplied by transport distance) of round wood took place by bundle floating. The corresponding figures were 59% for truck transport and 15% for railway transport.

LOG-LENGTH METHOD IN HARVESTING

The Finnish harvesting technology is a result of the forest ownership, the technical logging conditions, the forest management principles and the infrastructure described above. Compared with countries such as Canada, the United States and the Soviet Union, the economic and technical conditions are different and the ecological and environmental requirements often stricter.

The mechanization on off-road transport was started with farm tractors during the late 1950s. The first forest tractors in North Europe were Canadian-made articulated skidders. However, because the skidders and tree-length method were not fully satisfactory in the prevailing conditions, Sweden and Finland were forced to develop new machines and methods better adapted to their own special needs.

A new type of forest tractor, load-carrying forwarder, was developed in Sweden and Finland in the 1960's. The development of these machines was first characterized by the need for higher productivity and reliability. During the late 1970's increasing emphasis was put on ergonomic requirements. In the 1980's ecological and environmental expectations such as avoidance of soil compaction and rutting have affected machine and method development considerably.

As a result of this development, the forwarders and the log-length method gradually proved their superiority. The tree-length method today represents less than 1% of the off-road transport of timber.

A proven alternative for raising productivity and biomass recovery in early thinnings is based on whole-tree logging. The most laborious work phase of manual timber preparation, delimbing, is then abandoned and the above-ground biomass of small-sized trees is recovered almost entirely. The chainsaw worker only fells the trees, cuts them into 5-8 meter sections, and bunches the lightest sections to ease the loading of a forwarder.

DEVELOPMENT OF PRODUCTIVITY

In Finland the hand saw and axe were replaced by chain saw at the end of the 1950s and in the beginning of the 1960's. The introduction of the motor-manual timber preparation methods increased the productivity of work significantly. The muscle and machine input in the woods was reduced further by moving part of the traditional forest work, such as measurement, debarking, delimping, and bucking, to more favourable conditions at the mill.

At the same time, animal power in off-road haulage was replaced by farm tractors and forwarders. In the company operations today the haulage is based on load-carrying forwarders, and in the small-scale operations of self-active farmers on conventional farm tractors.

PRODUCTION OF PULP AND PAPER INCREASES

The future of the Finnish forest industry has been outlined in the Forest 2000 Programme, published in 1985. The programme was supplemented by the final report of the Forest 2000 follow-up Committee, which appeared in spring 1989. According to these studies, Finland's forest resources provide a solid basis for the development of the forest industry. Estimations of future consumption trends for various products also show that increasing amounts of sawnwood, wood-based panels, paper and paperboard will be consumed in Europe.

According to a study published by the FAO and ECE in 1986 on trends in the forestry sector, consumption of forest industry products in Europe should increase by the year 2000 as follows:

	low estimate	high estimate
	(%/yr)	
sawnwood	+0.5	+1.4
plywood	+1.0	+2.1
particle board	+2.1	+2.9
fibreboard	+0.6	+1.4
total paper and board	+1.6	+3.2
• newsprint	+1.5	+2.7
• printing and writing paper	+3.2	+4.7
• other paper/boards	+0.6	+2.4

The Forest 2000 Programme estimates that Finland's mechanical forest industry will hardly grow at all in the next several years. The production capacity of the sawmill industry has actually decreased by several million cubic metres in the 1980's. Similarly, the number of fibre board plants has dropped from the seven existing in the mid-1970's to the current three.

The report predicts the pulp and paper industries to be the main growth areas. It is estimated that production of wood pulp will grow from the 8 million tonnes recorded in the mid-1980's to a level of almost 12 million tonnes by 1995. The strongest growth, over 4%/yr, is expected in the production of mechanical pulp, with growth in the production of chemical pulp set at about 4%/yr.

Exports of chemical pulp are not expected to increase much above the current level. This means that the paper and board industry would have to increase its production by some 5%/yr. The most marked increase, around 7.5%/yr, is expected in the production of printing and writing papers (Table 8).

If production expands as predicted and consumption of paper and paperboard in Europe continues to grow as outlined above, then the proportion of European consumption accounted for by Finnish production would remain at approximately the current level. The proportion of the printing and writing paper market would grow by a few percentage points, but growth would be substantially slower than in past decades.

The expanding forest industry would also increase its yearly consumption of wood raw materials. According to the Forest 2000 Programme, by 1995 use of wood by the forest industry would be over 14 million m^3 greater than it was in the mid-1980's. The underexploitation of Finnish forests would, therefore, also be reduced considerably.

In the mid-1990's, however, the annual total drain on forest resources would remain millions of cubic metres lower than the level of annual forest growth.

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TABLE 8. Estimated production in 1990 and 1995 by Finland's forest industry. (Source: Forest 2000 Programme)

		Actual 1985 (*)	Estimated 1990	Estimated 1995	Growth, 1985-1995
			1000		%/yr
Conif. sawnwood	m^3	7633	7500	7500	-0,2
Plywood	m^3	586	600	600	0,2
Particle and fibreboard	m^3	724	730	730	0,1
Total paper and board	t	7343	9000	11300	4,4
• Newsprint	t	1715	1500	1500	-1,3
• Printing and writing paper	t	3115	4600	6400	7,5
• Other paper and board	t	2513	2900	3400	3,1
Total wood pulp	t	7913	9400	11200	3,5
• Mechanical	t	2865	3500	4300	4,1
• Chemical	t	5048	5900	6900	3,2

(*) Five-year average (1983-1987).

SWEDISH MIXEDWOOD MANAGEMENT

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On the whole, the biological conditions for forestry in Sweden and British Columbia are very similar. Although the species are not the same we have, in both countries, the dominating conifers pine and spruce, and also birch and aspen. Apart from this there are many differences.

British Columbia has twice as much forest as Sweden and it is almost all state owned. In Sweden 50% of the forests are owned by farmers, about 25% by companies and just under 25% by the state.

Another very important difference is that in Sweden sustained-yield forestry has been practiced for about 150 years. This forestry has been regulated by laws which all forest owners, including the state, must follow. Every forest owner is, for example, required to have an up-to-date management plan for his forest holdings. This plan must include statements of the need for silvicultural measures, suitable areas for felling, etc.

Sweden is close to the European market where there is a great demand for imported wood products. We have an extensive network of roads and railways and in the past also used many rivers for floating timber down to the coasts where most of our forest industries are still located.

Because of these conditions our industries have gradually learnt to utilize and sell products from all of these tree species.

Aspen is used to manufacture: paper pulp, fibreboard, matches and packing. We use birch for: paper pulp, plywood, veneer, fibreboard, particle board, furniture, folding rules, joinery, packing, pallets, toothpicks etc.

We have, therefore, no technical difficulties in processing birch and aspen, and although we fell about 11 million cubic metres of deciduous trees per year, we also import about half a million cubic metres per year.

The trend for the near future is rather clear. The country's pulp industry needs an increasing amount of hardwood raw materials. Sawmills, the board industry, the furniture industry and the joineries can all use more hardwood.

All seems well, but what kind of forests and silviculture do we have? On our growing stock of 23 million hectares (which includes bare ground and all age classes), we have an average of about 100 cubic metres per hectare. This volume consists of 15% deciduous and 85% conifers.

The growth is distributed somewhat differently, that is, 19% deciduous and 81% conifers. Deciduous trees grow faster than conifers.

This situation would appear satisfactory, provided the deciduous trees grew in pure stands. But this is not the case. Only 5% of our forests could be described as pure deciduous forest. This obviously means that a very large amount of the hardwood stock grows in mixed forests of pine or spruce, or both pine and spruce. In fact, as much as 70% of the hardwood volume can be found in mixedwood forests. This is a problem. Mixed coniferous forests also occur, of course, but as a rule these can be found on sites of average quality class where pine and spruce reach the same height up to the time of final felling. In these cases pine and spruce can be treated equally for the one, two or three thinnings which the stand will undergo during rotation. Therefore, this type of mixedwood forest does not present a management problem.

What then are the problems with deciduous trees? Aspen and above all birch are regarded as pioneer trees both in Sweden and in British Columbia. Every year 1% of our forest area in Sweden becomes bare forest land because of final felling. The result is that aspen and birch spread and grow at an enormous rate, especially after forest fires or controlled burning.

When these naturally regenerated deciduous trees appear on ground which, because of its site quality class, is best suited for pine and/or spruce, we regard them as weeds of the forest. Weeds which we could have controlled or eliminated earlier if we had used herbicides. We no longer have that alternative.

So what steps do we take? Because our principle objective is to produce good coniferous forests, it is therefore important to carry out site preparation, adequate for the site in question, very soon after final felling of the mature forest. This means that all clear-felled areas must be cleaned. Then soil scarification must be carried out in final preparation for planting.

If these preparations are carried out quickly and good coniferous seedlings are planted, there is a good chance that they will grow well.

In this way competition from the natural regeneration of deciduous trees can be reduced. One should be aware that on bare forest land surrounded by forest containing seed spreading deciduous trees, it is not advisable to expose more mineral soil than is necessary for good forest planting. A careful analysis can sometimes show that it is not necessary to prepare the entire area. In Sweden approximately 90% of forest area needs preparation before planting.

For areas where one can expect a high level of natural regeneration of deciduous trees, site preparation should absolutely not be carried out using a harrow or other continuously operating machine. One should use an intermittently operating scarifier which will make a patch for each plant. In Sweden the number of patches varies with the site quality class and is usually between 2,000 and 3,000 per hectare.

I would like to point out one exception to the rule of complete cleaning after clear-felling. Some areas of good ground, suitable for spruce production are low-lying in relation to the surrounding area. These areas are called frost holes as they can experience heavy ground frost in the early summer which can damage and sometimes kill small spruce plants. For these areas it is advisable to carry out a limited cleaning operation and leave about one thousand deciduous trees per hectare as a frost shield. When the spruce have grown to a safe height of about 3 or 4 metres, the frost shield can be removed. The spruce continue to grow and the deciduous trees are eliminated.

Let us now return to the ordinary thicket stage.

One or two years after planting an examination of plant survival is carried out. A certain level of morality must be accepted. However, if the level is too high, a supplementary planting must be done as soon as possible using the same species as originally planted. At this point, or at the very latest when the planted trees are 2 or 3 metres high, the Swedish Forestry Act requires all forest owners to carry out the first precommercial thinning if the young forest is growing too densely or, for example, if the proportion of deciduous trees in a coniferous forest is too great.

In precommercial thinning:

- the types of trees most suited to the ground are to receive priority - the trees of the best quality are to be saved - a suitable number of trees (in accordance with site quality class) are to be left and
- the distribution of trees over the area is to be relatively even.

In this question there is no conflict of interest between the forest owners and the law. There is a common goal. It is a matter of getting good quality trees of the right species as quickly as possible on the area in question.

During this thinning one also has the opportunity to leave a suitable number of trees for the remaining one, two or three commercial thinnings in the program before final felling. These thinnings provide further opportunities for controlling the mix of species and final felling of all deciduous trees can be done at the time of the final thinning. In this way a stand of pure conifers can be achieved before final felling.

Precommercial thinning is usually carried out with brush saws. However, since the ban on herbicides, intensive efforts have been made to try to develop a mechanized technique. We now use rotating blades mounted to the crane rotator of a small forestry tractor. My company, STORA, has taken part in this work and the results have been so successful that ten units are now being procured.

Compared to manual operation with brush saws this new technique costs less, and the damage to remaining plants is quite acceptable. A requirement is that the work be carried out before the conifers become too big. They should be less than 1.5 metres if the ground clearance for the tractor is 8 to 9 decimetres.

An additional advantage with the mechanized technique is that it can also be used in 60 to 70 centimetres of snow. It can, therefore, be used through most of the year.

I do not know about the birch's stump sprouting ability nor the quantity of root suckers produced by aspen in British Columbia. However, our experience in Scandinavia has shown that the best thinning results for birch have been achieved during the few weeks of early summer directly after the new leaves have fully developed. At this stage the trees have spent their energy on producing the new crop of leaves and their ability to sprout is greatly reduced.

If deciduous trees are cleared away at the right time and with care, and by that I mean that stumps should be as short as possible and the trees completly cut away from them, then one thinning should be enough in most cases.

On very fertile ground it will sometimes be necessary to repeat the thinning operation. Especially if the first thinning was carried out too early or the stumps were not cut short enough.

I have now covered the establishment of new forest and silviculture in your forests aimed at reducing the influence of deciduous trees in coniferous forests.

What action do we take when managing forests that are mature or over mature with a mix of birch and aspen? How do we carry our reproduction cutting aimed at having the lowest possible level of deciduous trees in the next generation of trees?

I suspect that this might be a big problem in British Columbia and that it is connected to the lack of hardwood processing industries.

However, as I am not an expert on industry I will return to forestry. As I mentioned earlier, in Sweden we have been practicing sustained-yield forestry for a very long time, where the deciduous trees are gradually eliminated during thinning. Mixedwood during final cutting is, therefore, not a great problem. But when it does occur, we often work according to the following model.

In stands with a birch mix, thinning is done 10 years before final felling to remove all birch trees. In the thick forest no sprouting occurs from the birch stumps and a well planned system of strip roads reduces any negative effects on the conifers to a minimum.

Stands with a mix of aspen are treated differently. To avoid root suckers the aspen trees must be killed before final felling of the stand. To get the best results, notching, if allowed, or girdling should be carried out at least 3 years beforehand. There are different methods of girdling. I believe the cheapest and best results can be had by using a light chain saw and cutting through the bark around the tree.

The term silviculture covers what I have described so far.

In Sweden silviculture means: planning, surveying, mapping, clearing bare land, ground preparation, planting, removing deciduous trees from mixed stands, precommercial thinning, draining, fertilizing, nature conservation.

Silviculture costs money.

STORA, the company I represent, owns about 1.5 million hectares of forest. Rotation for these forests is on average about 100 years. This means that every year we clear fell about 15,000 hectares and this area is then treated as I have described.

The total cost for this silviculture is about 50 million Canadian dollars per year. That is about 33 dollars per hectare of forest land or 13 dollars per felled cubic metre.

And now a short summary of how the problem of mixedwood can be reduced in the future.

Prepare the site, plant conifers, clear deciduous thickets, reduce the deciduous mix when thinning, cut down birch trees in mature forests 10 years before final felling and kill aspen trees in these forests for at least 3 years before final felling.

NORTHERN MIXEDWOOD RESEARCH - IMPLICATIONS OF GENETIC IMPROVEMENT

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ABSTRACT

The history, potential and state-of-art of the breeding programmes in aspens, poplars and birches, with reference to northern mixedwoods, is briefly outlined. The potential for genetic improvement is considerable, but a well planned re-activation of these programmes is needed if improved stock is to be produced within the next 10-15 years. The management of mixed species plantations could pose additional problems. Hybrid poplar clones could be successfully grown on alluvial terraces in the major river valleys in the Boreal Forest Region, but we have neither tested clonal varieties nor plantation management practices for such plantings.

Criteria for the identification of superior and inferior genotypes of aspen are not well established. The replacement of inferior aspen stands with a different species seems more feasible.

INTRODUCTION

Canada has recognized the need for better utilization of trees and increased forest yields. Recent actions by forest industries and governments emphasize this recognition. Increased efforts in genetic improvement must be an important part of these undertakings.

The genetic improvement of trees is a relatively long term proposition, and it's results are only seen in a new generation of forest. However, genetic improvement work with forest trees in Canada started more than fifty years ago. Tree breeding programmes are well established in most provinces, using species which have been considered commercially important. In many cases, new generations of forests are already established with genetically improved stock. Nevertheless, in order to meet the needs of intensified forest management, and with additional tree species gaining commercial importance, some re-orientation of genetic improvement programmes will be needed.

Aspen, birch, spruces and pines appear to be the important species of northern mixedwoods. Genetic improvement programmes in Canada are well established and active with spruces and pines, which have been considered commercially important species.

However, these programmes are incomplete and inactive with aspen and birch, which were considered weed species until recent times. This situation is exemplified by the fact that there was not a single report on genetic improvement work in aspens presented either to the annual meetings of the Poplar Council of Canada in 1985 (Timmins, Ontario) and 1988 (Edmonton, Alberta) which focused on aspen, or in the series of articles published in Forestry Chronicle (1989) under the common title "Managing for Aspen - A Shared Responsibility."

BREEDING PROGRAMMES IN HARDWOODS

Breeding programmes in poplars (including aspens) and birches have been more active in Europe than in North America. Poplar culture in Europe and Asia goes back to biblical times, and so does the selection, propagation and use of several cultivars, such as Lombardy poplar. The introduction of *Populus deltoides* some 200 years ago was undoubtedly the most important single event in the modern story of poplars in Europe (FAO 1979). Soon afterwards, natural hybrids between this American species and the European *P. nigra* started to appear, giving rise to *P. x canadensis* (*P. x euramericana*) cultivars, the culture of which spread to all of Europe and other continents.

From the 1930's, breeding programmes with poplars intensified and resulted in more superior clonal selections. Outstanding examples of these are in Italy (Prevosto 1969) and Belgium (Muhle Larsen 1970). The new clonal selections of hybrid poplars showed significant improvement over the spontaneous *P. x canadensis*. These new generations of clones, resulting from well planned genetic improvement work, outperformed the early selections significantly, sometimes by 2-3 times. These new clones were also better in site adaptation, pest resistance and wood qualities (IUFRO 1979).

Poplar breeding in North America also started in the 1930's; in the U.S.A. (Schreiner 1970) at the North Eastern Forest Experiment Station, and in Canada (Heimburger 1968) at the Petawawa National Forestry Institute. Breeding in the U.S.A. included a larger variety of poplar species (such as different species of Tacamahaca section in crosses with cottonwood-type poplars) than in the 1930's to 1950's in Europe, and resulted in very good clonal selections of hybrids. However, the poplar culture never spread in larger areas, because of the relative abundance of timber and different needs of the forest industry in North America at the time.

Aspen breeding started at about the same time as poplar breeding. In Europe, the Scandinavian countries and Germany, among others, had good results especially with *Populus tremula x P. tremuloides* hybrids (Johnsson 1956). These were superior to selections from native *P. tremula*. In North America, work focused on *P. tremuloides x P. tremula* and *P. alba x grandidata* hybridization, and the development of triploid aspen (Heimburger 1968, Einspahr and Winton 1977). Despite the good results obtained in these breeding programmes, aspen plantations have not spread to large areas either in Europe or in North America. The limitations included problems associated with vegetative propagation of aspen varieties and pathogens of aspen, especially the canker diseases. Furthermore, in North America, less demand for aspen wood has contributed to limited plantation management of aspens.

There is a long tradition of birch breeding in Europe. For example, in Finland, seed orchards currently produce all of the selected European white birch (*Betula pendula*) seed required for planting (Ferm et al. 1985). Progeny tests in Finland indicate a 30% improvement in volume growth from present seed orchard material compared to non-bred provenances (Lepisto 1981). Properly managed birch plantations established with genetically improved stock grow excellent trees and give a completely different impression from the one we get when looking at mostly degraded stands of paper birch in Canada.

Genetic studies in birches began in North America in the 1940's (Clausen and Garrett 1969), but genetic improvement programmes have never really advanced. More interest has been paid to yellow birch, a high quality timber species of the northeastern hardwood zone, than to paper birch. It is likely that selection and breeding in paper birch would result in gains similar to the ones experienced in Finland. Also, properly managed plantations with improved stock would bring increased yields and high quality timber.

POTENTIAL FOR GENETIC GAIN IN MIXEDWOOD STANDS

The potential for genetic gain in mixedwood stand species is considerable. As discussed, in Finland, stock from seed orchards grown in properly managed plantations produces a 30% gain in volume growth. Poplar clones resulting from good breeding programmes are several times better in growth and form than the natural trees. Considerable improvement can be expected from spruce and pine breeding programmes as well. The gains expected in these species from seed orchards range from 4% to 20% (OMNR 1987). The question is whether such potential gains can be realized with the present limitations in breeding programmes and management practices.

Breeding programmes with white spruce, sitka spruce, black spruce, jack pine and lodgepole pine have advanced in Canada and in most localities these programmes can supply selected seed from either seed production stands or seed orchards. This seed is a guarantee of successful plantation management and improved growth, although at a more moderate level of gain (4% to 8%) than discussed above. Breeding programmes with aspen and birch are not active at the present time in Canada and can not deliver genetically improved stock in the immediate future. Newly activated programmes could build on the previously accumulated knowledge and genetic resource, but would need considerable support and at least 10-15 years to deliver.

The second limitation in using the potential gains offered by genetic improvement lies in mixedwood management practices. There is very little experience in planting and managing plantations of mixed species. Considerable experimentation and time would be required to gain such experience. Also, specially selected stock which tolerates, or even favours growth in mixed stands may be needed. We have not tackled this question as yet. Naturally, managing blocks of pure, single species plantings would be an entirely different proposition. There is considerable experience with management of pure plantations,

especially of coniferous species, in Canada. There is also some experience with managing hybrid poplar plantations. There is much less experience with aspen and birch plantation management in Canada. However, this problem is being undertaken in conjunction with management of aspen stands. Some earlier references (Heeney et al. 1980, Hambly 1985), several reports presented at the Poplar Council of Canada annual meeting in Edmonton, Alberta, 1988, the Joint Technical Session of the Canadian Institute of Forestry's working groups in Prince Albert, Saskatchewan September, 1988 (Forestry Chronicle 1989), and several presentations at this Symposium witness this situation. Also, foreign experience could be used as a first resource when needed.

POTENTIAL FOR THE USE OF HYBRID POPLARS IN THE MAJOR RIVER VALLEYS OF THE BOREAL FOREST REGION

In the context of this discussion we consider hybrid poplars the clonal varieties of *Aigeiros* (cottonwoods) and *Tacamahaca* (balsam poplars) sections and their interspecific hybrids. Such hybrid poplars have been used extensively in the poplar cultures of Europe, and also in the U.S.A. and Canada (especially in Eastern Ontario - OMNR 1983). Clonal selections are available for a variety of soils (most of these will grow very well on alluvial soils), but only in temperate climates. Trials which I established in the 1970's with a variety of hybrid poplar clones in Boreal Ontario failed, mainly because of frost damage (Zsuffa 1979). However, several selections of native plains cottonwood (*P. sargentii*), balsam poplar (*P. balsamifera*), jackii poplar (*P. x jackii*), and of crosses of these species with other balsam poplar species and hybrids survived and grew very well. Some of these crosses were done by Indian Head Nursery (Cram 1968), and others were selected and hybridized in Ontario. In small trials, on good soils which were properly controlled for weed competition, these clones grew as well as the best clones in south-eastern Ontario. Unfortunately, this programme did not receive support at the time and was discontinued. However, some of the clones, especially those developed by Indian Head Nursery, are readily available and could be used for clonal screening trails. A limited number of the best clones could then be selected for plantation management trials, and eventually for operational planting. In my experience from Northern Ontario, soil quality and site management, in addition to clones, are very decisive factors influencing the success of plantings. Thus, fields with shallow, heavy subsoils, moisture stresses, and weed competition can frequently be causes of failure.

In summary, our experience with hybrid poplar plantations in the boreal forest region is very limited. However, initial clonal stock can be obtained for screening trials and development of proper management techniques. Small scale trials in Northern Ontario have shown that good clonal selections on adequate and properly managed sites can grown as well as anywhere in hybrid poplar plantations. With good support, clones could be selected and management methods established within the next 10 to 15 years.

IDENTIFICATION AND PROPAGATION OF SUPERIOR PHENOTYPES IN NATURAL STANDS

Superior phenotypes (plus tree selections) are an important starting point for breeding programmes. Plus tree selections in spruces and pines have been underway for some time now, but the same can not be said for aspens, cottonwoods and birches. The criteria for plus tree selection and the methods for initial propagation of these species are important considerations.

The criteria for plus tree selection of conifers are well established (Morgenstern et al. 1975). Some of the same criteria (such as age, growth and form of the trees, freeness from pathogens) apply also to hardwood species. However some special considerations will apply as well. In the case of aspen and balsam poplar (black cottonwood), because of root suckering, stand formations could be of one clone only or intimate mixtures of very few clones (genotypes). Special attention has to be paid in these cases to select just one tree per clone, because additional selections will be superfluous and misleading duplications. Also, stem decay is an important criterion for aspen: in some healthy-looking aspen trees most of the internal wood could be decayed, and the relationship of this symptom to genotype and environmental conditions (site, age, silviculture) can be very diverse, specific and confusing (Thomas 1968, Basham 1979). Also, some particular pests, such as the bronze birch borer (*Agrilus anxius*) in the case of birch selection, may require consideration.

The propagation of selected trees could be accomplished by grafting, in a similar fashion as in other tree species. Cleft grafting is an often preferred method for hardwood species (Wright 1976). Species which produce root suckers, such as aspen, black cottonwood and balsam poplar, can also be propagated by root-cuttings. Zufa (1971) describes a convenient method of propagation by unearthing and taking pieces of roots from selected trees and producing suckers from the same. Propagation by stem cuttings taken from mature trees in difficult even with

species such as cottonwoods, which otherwise can be propagated easily by stem cuttings. In these species, taking cuttings from young coppices, epicormic shoots or suckers will facilitate the rooting.

IDENTIFICATION OF INFERIOR GENOTYPES IN STANDS AND THEIR REPLACEMENT

We perceive trees in stands as phenotypes, the products of the tree's genotype and its environment. We can usually detect the genotype only after testing the tree's performance in replicated progeny or clonal trials. However, for characteristics which are under strong genetic control and not modified considerably by environment, we can detect the genotype directly by observing these traits on the tree. Some of the traits considered as being under high genetic control are stem form, branching angle, fiber length and wood density. Other characteristics, such as growth, and in many cases resistance to decay and other pathogens, can be influenced considerably by site and age, among other factors. Thus, the identification of inferior genotypes and stands can sometimes be a complicated task, and judgments made on the basis of growth in original stands only can be misleading.

Replacement of species may be needed on some poor sites, regardless of the genotype. This may be the case for replacement of aspen with lodgepole pine on sites considered dry for aspen. The replacement of confirmed inferior genotypes of aspen may require a similar solution. This is because replanting of aspen cut-over sites with other, superior aspen varieties can be a very difficult task (Doucet 1989). It is likely that the roots of logged aspen will sucker, even when scarified and treated with herbicides, and will initially compete with the planted variety. Also, after a few years, the distinction of planted stock from suckers will become increasingly difficult, and the measures needed for cleaning the sucker-competition very expensive. An easier way of replacement will be with a different species, either another poplar species distinguishable form the natural aspen growth, or with a coniferous species suiting the site.

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PROTECTING UNDERSTORY WHITE SPRUCE WHEN HARVESTING ASPEN

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ABSTRACT

This report covers the silviculture component of a joint FRDA-funded project involving NoFC (ForCan), FERIC (West), the AFS and four companies in Alberta. Nine mixedwood stands with understories were scheduled for aspen harvesting in 1988 using a variety of conventional and modified techniques. This report addresses six of these stands.

A brief background on trends in aspen utilization in mixedwood stands with understory spruce is followed by a theoretical two-stage model for tending and harvesting such stands.

Harvesting results — seen as practical tests of the model from a silvicultural perspective — are given in terms of understory damage by cause, yield implications for residuals, and recommendations based on data and experience.

INTRODUCTION

Nature and Extent of Regional Boreal Mixedwoods

The distribution of boreal mixedwoods within four regional Forest Sections (Rowe, 1972) is illustrated in Figure 1. They occupy an estimated 150 000 ha, representing about one-third of the productive forest land base in the prairie provinces. This paper focuses on the white spruce *(Picea glauca* (Moench) Voss) component of mixedwoods which occurs as an understory with aspen *(Populus tremuloides* (Michx.), balsam poplar *(Populus balsamifera* L.) and white birch *(Betula papyrifera* Marsh.). Data on the nature and extent of spruce understory stands are not available from current inventories. Recent surveys in Alberta have shown understory stands to be very significant, occupying up to 80% of stands currently inventoried H (hardwood) and HS (hardwood-softwood) (Brace and Bella, 1988, personal comm. D. D'Amico - Blueridge Lumber (1981) Ltd.)

NEED FOR UNDERSTORY SPRUCE PROTECTION

Future supplies of commercial white spruce depend in the long run upon successful establishment of new stands, which has proved to be relatively costly and ineffective to date (Drew, 1987, 1988; Peterson, 1989), even though it has been the subject of considerable regional research for many decades on mixedwood sites (Jarvis et al. 1966). In the shorter term, understory stands occurring naturally in association with hardwoods are a primary source of spruce. Until recently, these understories have developed to commercial size through natural succession under the protection of the hardwoods. However, the demand for aspen, which accounts for 80% of regional hardwoods, is rising dramatically, particularly in Alberta (Brennan 1988; Ondro 1989) where over 70% of the aspen AAC has been committed for new and proposed developments by 1993 (Table 1). Many stands inventoried as H and HS are now being scheduled for aspen harvest using conventional harvesting equipment and procedures, jeopardizing the associated spruce understory and the future softwood timber supply.

Figure 1

Boreal mixedwood: B15, B.18a, B.19a, B.24

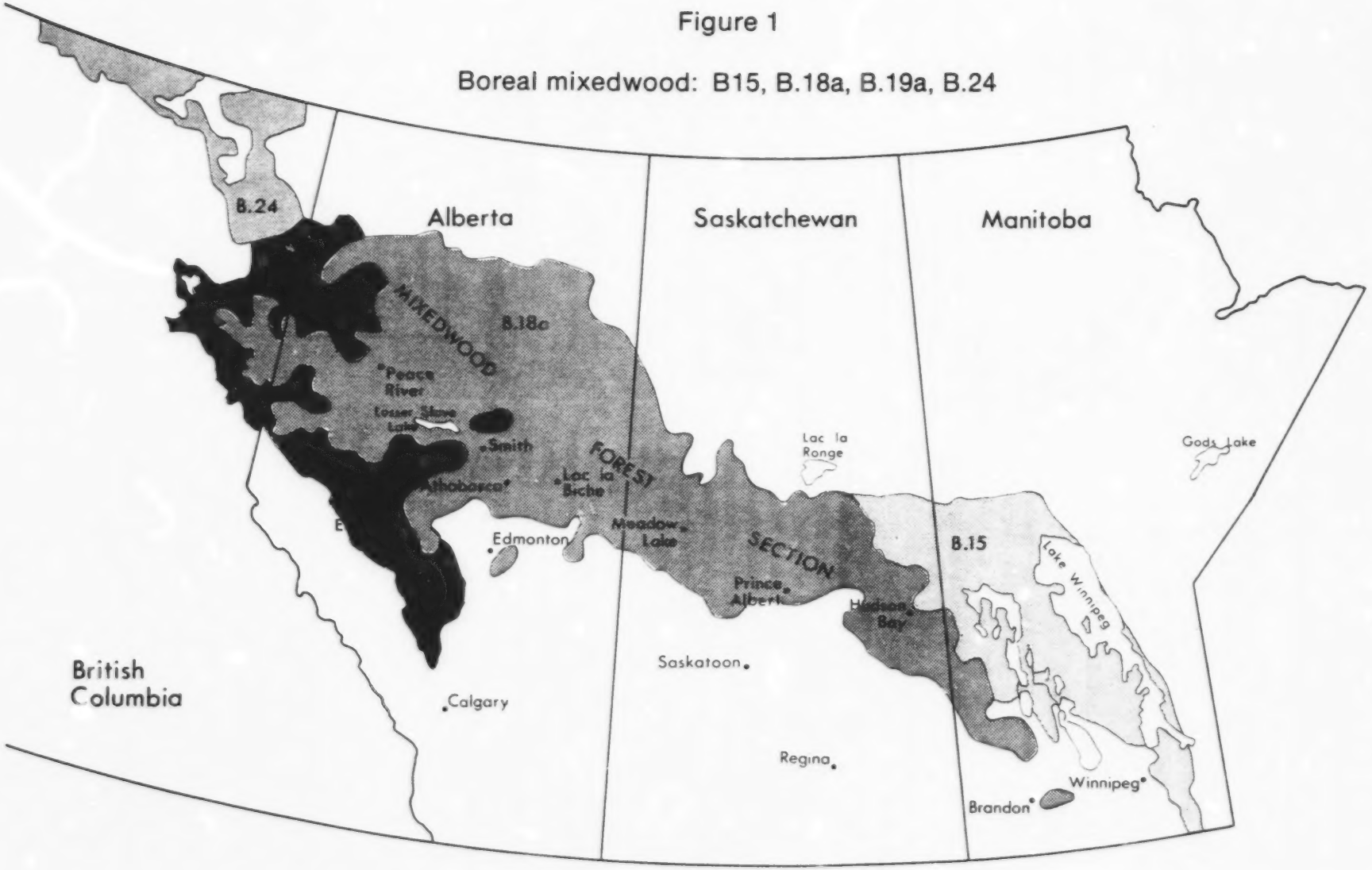


Table 1. Utilization trends and current AAC - aspen - Western Canada (million m^3)

	Utilization Trends[1]				Current AAC[2]	% AAC committed 1993 (est)
	1978	1983	1988	1993 (est)		
Manitoba	.06	.16	.14	1.03	1.8	57
Saskatchewan	.30	.37	.84	1.70	2.6	65
Alberta	.05	.17	.89	6.00	8.4	71
B.C. (Northwest)	-	-	.16	.16(+)	3.5	5
				8.89	16.3	55

[1]Summarized from information provided by provincial governments.

[2]From Woodbridge, Reed and Associates; 1989.

The need for protection of spruce as a component of boreal mixedwoods goes beyond concern for the future commercial softwood timber supply. Concerns also include fisheries and wildlife habitat, aesthetics and recreation, a general dissatisfaction with clearcutting in mixedwoods and a strong interest in mixedwood perpetuation, as expressed recently in 41 public meetings on forestry development in northern Alberta (Concord Scientific Corp., 1989). Also, at a recent forum on the environment organized by the Canadian Pulp and Paper Association (CPPA), industry leaders strongly expressed forest management concerns much beyond timber supply (Addison et al. 1989). There is clearly a need to develop new approaches to mixedwood harvesting, particularly where spruce understories need protection.

In areas with no demand for aspen and where white spruce has a priority, other scenarios for understory white spruce release not entailing problems of harvest technology and other associated risks to the understory should be considered in order to perpetuate or increase the spruce component of mixedwoods.

TWO-STAGE TENDING AND HARVESTING MODEL

Figure 2 illustrates a model which has been designed to accommodate two harvests of aspen in a 120 year cycle and to realize the yield potential of associated understory spruce. The model is described by Brace and Bella (1988). Beginning with an aspen stand aged 60 and understory spruce averaging 40 years of age, the aspen and all spruce over 25 cm dbh could be harvested, leaving a released spruce understory. Sixty years later the mature spruce and a 60-year-old aspen stand which originated from suckers at the time of initial cut could be harvested again and options for future management of the land base considered. The model does not necessarily imply a sustained yield policy for white spruce on this specific land base. The future of the land base - whether hardwood, softwood, or mixedwood - poses many silvicultural challenges, some of which are addressed by Navratil et al. (1989).

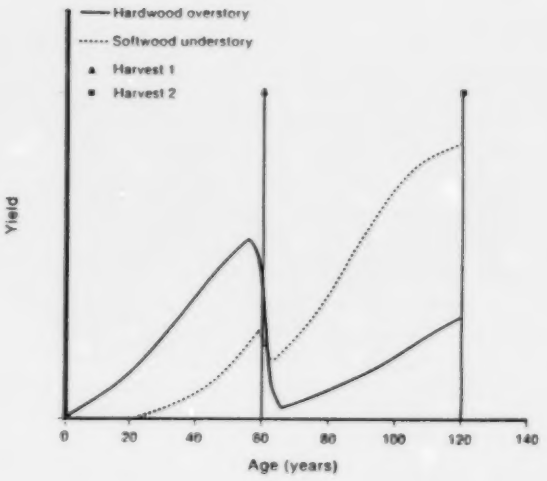
Advantages of the Model

Advantages of the model would include:

a) reduction or avoidance of the costs and risks associated with establishing and growing spruce on mixedwood cutovers,
b) improved utilization of aspen and increased spruce AAC through increased growth and shorter rotations for spruce released from the understory (tending component of model),
c) maintenance of spruce-related landscape aesthetics, wildlife habitat and recreational values, thereby addressing major shortcomings of the clearcutting

Figure 2

Generalized two-stage tending and harvesting model.



system as now practised on many mixedwood sites,
d) contribution to solving the problems created where hardwood and conifer harvesting rights are held by different companies on the same land base, and where protection of understory spruce is a priority for the softwood user.

Disadvantages of the Model

Some of the disadvantages of the model would include:
a) uncertainty about the feasibility of adapting available harvesting technology to protect the understory under a range of stand age, density and site conditions,
b) potential for windthrow of released spruce, particularly on moist sites, as well as the risk of leader-weevilling in released spruce,
c) problems with estimating the growth and yield of mixed-species stands of released spruce and new aspen suckers.

GROWTH AND YIELD AND OTHER MIXEDWOOD MANAGEMENT IMPLICATIONS

Brace and Bella (1988) developed growth and yield estimates for spruce released at age 40 and harvested at age 100 in the previous model, for one specific site. Results indicated that if 600 viable 40-year-old spruce residuals survive to age 100 they could yield 550 to 590 m^3/ha. Yields would be 10% lower for 400 trees and 30% lower for 200 trees. It is assumed that aspen suckers will occupy any available space in the stand, either as pure clumps or in mixture with spruce, and will supplement softwood yield as spruce stocking declines, up to the yield potential of the site.

After harvesting aspen to release spruce it is not uncommon for a stand to develop separate clumps of aspen suckers and spruce residuals, as well as areas where the species intermix. Because of the variety of conditions possible in such mixedwoods with respect to the density and distribution of species components, growth and yield prediction for spruce and associated hardwoods is difficult, and reliable techniques are not yet available. Such variety, seen as an impediment to growth and yield prediction, is often desirable from other perspectives, for example to provide habitat for particular wildlife species and for landscape aesthetics.

Increases in hardwood utilization, coupled with public demand to maintain mixedwoods for a variety of non-timber purposes are challenging traditional softwood bias in mixedwood management, requiring management objectives beyond softwood silviculture and growth and yield and creating the need for an effective multi-disciplinary approach to both management planning and operations.

FIELD TEST OF THE TWO-STAGE MODEL

Project and Participants

A cooperative mixedwood harvesting project which serves as a field test for the two stage tending and harvesting model was initiated recently under the Canada-Alberta Forest Resource Development Agreement (FRDA). Co-operators include the Northern Forestry Centre of Forestry Canada, the Forest Engineering Research Institute (FERIC-west) the Alberta Forest Service (AFS), Pelican Spruce Mills (now Weyerhaeuser Canada Ltd. (Alberta)), Weldwood of Canada Ltd., Blueridge Lumber (1981) Ltd., and Millar-Western Industries Ltd. There are a total of nine study stands, 3 in each of the areas shown in Figure 3. This report addresses the stands harvested in the Drayton Valley area (identified in the report as DC (control), D1 and D2) and in the Hinton area (HC (control) H1 and H2). All nine stands should be completed by April 1990. The final two stands will be harvested during winter to determine the effects of cold weather operation on understory damage. This is particularly important since many sites in the region are only accessible for winter operations.

Objectives

The primary silvicultural objectives of this project were:
a) assess damage to residual spruce trees released during harvesting of the aspen overstory; and
b) monitor subsequent development of the residual spruce (growth, windthrow and weevil risk) and of new aspen suckers (density, growth), and the utility of the approach for addressing non-timber mixedwood management issues.

This report addresses objective (a), emphasizing the residual spruce crop between 2.5 and 14 m high which are the trees most likely to survive and grow to maturity, because they are tall enough to compete with new aspen suckers (Johnson, 1986) and should be reasonably windfirm on upland sites.

Harvesting costs, equipment productivity and details of operational procedures for each stand harvested in the project have been reported by Sauder and Sinclair (1989).

Figure 3

White Spruce Understory

Location of Study Stands
Project - 1480

1 Drayton Valley
2 Hinton
3 Blue Ridge

Procedures and Pre-Harvest Status of Stands

Table 2 describes the harvesting methods and procedures (treatments) applied in each stand. Feller-buncher/grapple skidder harvesting equipment was used in all cases except treatment 2 in Hinton (H2) which used a Swedish shortwood (Rottne) processor and forwarder combination.

Table 3 presents pre-harvest statistics for each stand treated. There were substantial differences between stands in terms of hardwood and softwood overstory composition, volume and quality, average stem size and softwood understory density and distribution. This, combined with the variety of equipment and procedures (Table 2) makes detailed comparisons between stands inappropriate and requires a case study approach based on data and observation.

RESULTS AND DISCUSSION

Controls

Felling and forwarding in stands DC and HC (Table 4) were carried out using conventional equipment, according to prevailing operational ground rules in Alberta, clearcutting the aspen with no concern about understory damage or mortality. No restrictions were placed on the felling sequence or on travel routes for forwarders (skidders). There was apparently a psychological effect of the protection philosophy being applied to other stands, as operators made unusual attempts to preserve some understory spruce clumps. Some spruce were also protected within clumps of non-merchantable hardwood. Control stands are therefore predominantly clearcut, with a few dense understory spruce clumps and scattered individuals and should regenerate primarily to aspen suckers. Control stands primarily used to provide comparative cost and productivity data for the FERIC component of the project.

Felling Mortality and Damage

In general felling caused less mortality but more damage than forwarding in treatments D1, D2, H1 and H2 (Table 4). Felling mortality was minor, varying from 1 to 5%. Felling damage varied from 11 to 19% for feller-bunchers (D1, D2, H1) but was 40% for the Swedish Shortwood Treatment (H2), primarily because the shortwood processor had much less directional felling control than the feller-bunchers. The relatively high initial stand density (1994 trees/ha) may also have been a factor.

Felling damage was recorded mainly as broken tops and branches, bark scrapes on stems, and leaning trees. The Swedish shortwood processor caused a relatively large proportion of bark scrapes and leaning trees. Much of the processor-related damage was minor and would be considered acceptable on residual crop trees.

Large individual spruce, characteristic of many mixedwood stands containing understories, caused considerable damage when hand-felled in treatments D1 and H1. This poses a dilemma in such stands because their high timber value has to be balanced with understory protection priority, blowdown hazard, and need for seed trees when setting treatment objectives.

Equipment-related factors affecting understory damage include size and type of carrier and boom and size and type of felling head. Multiple entries for felling and forwarding also increase damage. These sources of damage can be minimized by matching equipment and harvesting pattern to stand conditions (personal comm. E.A. Sauder, FERIC west). The feller-buncher used in stands D1 and D2 had no boom, so had to approach each tree before felling, increasing understory damage, but it was also relatively narrow, which compensated to some extent for the lack of a boom. The feller-buncher used in H1 had a 3-4 m boom so could reach for trees, but it had a large counterweight which caused damage when turning and a relatively large felling head which caused damage when being positioned for a cut. Both types of feller-buncher carried the trees upright after cutting and bunched them on skid trails, which reduced subsequent forwarding damage and mortality. The relatively good performance of the feller-buncher in H1 was noteworthy, considering the initial understory density (Table 4), reflecting effective planning as well as operator experience and attitude.

The Swedish shortwood processor had a 10 m boom but was unable to take full advantage of it due to the large average size of the aspen being felled (mean dbh 22.1 cm., Table 3) making it necessary to move toward many trees to fell them, resulting in a zig-zagging pattern in the stand rather than maintaining a relatively straight course and reaching for the trees. In addition, it had little directional felling capability and it also caused damage as it shifted felled trees back and forth in a horizontal plane while delimbing and bucking. It had an advantage over the feller-bunchers in being able to swing the felling head above the understory when reaching for aspen, and the smaller felling head caused less damage when being positioned for a cut. This machine would cause much less felling damage if it were operated in a stand where the trees being cut were small enough to allow it to maintain alignment in the stand and take full advantage of the 10 m boom and the smaller crowns of younger aspen would compensate to some extent for the lack of directional felling capability. A large single-grip machine should function more productively

Table 2. Harvesting Methods and Procedures Applied by Location and Treatment

Treatment	Function	Location	
		Drayton Valley (D)	Hinton (H)
Control	Felling	Feller-buncher on tracked loader with shear head	Feller-bunchers on tracks, with shear head
	Forwarding	Grapple skidders - full tree	Grapple skidders - full tree
	Procedures	Conventional clearcut. All species topped, delimbed and bucked on the landing by hand	Conventional clearcut. Stroke delimber and slasher on landing
Treatment 1	Felling	Same as control	Same as control
	Forwarding	Same as control - full tree	Same equipment as control, but tree length instead of full tree and rub-stumps used along trails
	Procedures	Main stand trails located before harvesting and Feller-buncher operator chose other trails. Conifer hand-felled after aspen and skidded separately. All species topped, delimbed and bucked on landing by hand	Main skid trails prelocated and secondary trails flagged before harvesting. Conifer and aspen felled and bunched at same time and limbed and topped before skidding. Oversize spruce hand felled. Stroke delimber and slasher on landing.
Treatment 2	Felling	Same as control	Rottne double grip processor (fell, limb and buck)
	Forwarding	Same as control (full tree)	Rottne forwarder
	Procedures	Trail designation as in treatment 1. Conifer and aspen machine - felled and thatched down on skid trails by feller - buncher. All species topped, delimbed and bucked on landing by hand.	Highly skilled operators selected trails and controlled operation

Table 3. Pre-harvest Stand Statistics by Treatment

Standard treatment	Area (ha)	Species group	Aspen age (yrs)	Total Stand				No. understory spruce/ha by Ht class (m)		
				Stems/ ha	Mean Dbh (cm)	Total vol. (m^3/ha)	Vol./tree (m^3)	2.5-7.5	7.6-14	2.5-14
Drayton Valley Control (DC)	20	Aspen	110+	140	31.0	114	.81			
		Poplar		395	17.4	70	.18			
		Birch		136	25.4	58	.43			
		Spruce		868	9.8	46	.05	412	138	550
		Total				288				
Drayton Valley Treatment 1 (D1)	20	Aspen	110+	243	29.5	170	.70			
		Poplar		216	18.8	47	.22			
		Birch		14	20.6	4	.29			
		Spruce		691	9.4	31	.04	268	123	391
		Total				252				
Drayton Valley Treatment 2 (D2)	15	Aspen	110+	284	26.3	148	.52			
		Poplar		143	21.3	35	.24			
		Birch		559	5.5	-	-			
		Spruce		464	9.0	11	.02	249	74	323
		Total				194				
Hinton Control (HC)	18	Aspen	70+	853	18.9	170	.20			
		Poplar		222	17.6	30	.14			
		Birch		-	-	-	-			
		Spruce		4125	5.7	47	.01	1371	373	1744
		Total				247				
Hinton Treatment 1 (H1)	14	Aspen	70+	1085	19.1	222	.20			
		Poplar		253	13.1	18	.07			
		Birch		-	-	-	-			
		Spruce		1218	6.3	5	.01	533	207	740
		Total				245				
Hinton Treatment 2 (H2)	18	Aspen	70+	470	22.1	135	.29			
		Poplar		315	15.8	29	.09			
		Birch		-	-	-	-			
		Spruce		3951	5.9	45	.01	1607	387	1994
		Total				209				

Table 4. Percent Damage to Understory Spruce Trees 2.5 to 14 m During Aspen Harvesting

Treatment	Initial Nt/ha	Undamaged	Felling		Forwarding		Harvested	Other	Total
			Damage	Mortality	Damage	Mortality			
DC	550	33	19	1	13	28	6	-	100
HC	1744	13	16	4	14	49	3	1	100
D1	391	44	19	-	11	24	2	-	100
D2	323	65	11	1	9	13	1	-	100
H1	740	51	18	1	10	18	1	1	100
H2[1]	1994	29	40	5	(11)	(14)	1	-	100

[1]The Swedish shortwood systems is not directly comparable to others due to the combined functions of felling, delimbing and bucking. Damage and mortality identified as forwarding was not distinguishable from skidder damage but primarily caused by the delimbing and bucking functions. Forwarding effects were minor.

with up to 20% less understory damage, than the double-grip machine used in stand H2 (personal comm. O. Hannula, Weldwood of Canada Ltd.).

Forwarding Mortality and Damage

In general, forwarding caused considerably less damage but more mortality then felling in all cases (Table 4). Damage ranged from 9 to 11% and occurred mainly as bark scrapes and leaning trees. Forwarder damage was almost entirely skidder-caused.

Damage statistics for the Swedish shortwood forwarder are misleading because they really reflect the delimbing and bucking functions of the processor as described earlier, but could not be separately identified. The shortwood forwarder itself did minor damage when loading logs - mainly upper stem scrapes - and virtually no damage during forwarding as it was the same width as the processor.

Forwarder-caused mortality varied form 13 to 24% and again was almost entirely skidder-related, since the 14% shown for this Swedish forwarder is really related to delimbing and bucking functions. The good performance of the skidder operation in relatively dense understory in H1 is noteworthy, reflecting effective coordination of the skidder and feller buncher functions, and operator experience and attitude. The 24% skidder related mortality in D1, compared to 13% in D2 in a stand of comparable initial understory density, and 18% for H1 in a stand of relatively high initial understory density is largely a reflection of protection effort, not of equipment.

The Importance of Protection Effort

Table 5 summarizes pre- and post-harvest understory spruce density according to degree of protection effort, which was assigned to reflect the planning, layout, supervision and crew experience and attitude which characterized each case. Figure 4 shows that protection effort was more significant than type of equipment used, an observation which is consistent with the results of previous mixedwood harvesting studies (Brace and Stewart 1974, Froning 1980).

Growth and Yield and Other Management Implications

If growth and yield data for spruce released at age 40 and harvested at age 100 (Brace and Bella 1988) are applied to the spruce residuals in Table 5, treatment H2 is overstocked and should perform as a relatively pure spruce stand if the trees were well distributed, yielding from 550 to 590 m^3/ha, whereas the lower-stocked treatments (DC, D1, D2) should yield spruce in the order of 30% less. Aspen yield would be expected to increase in proportion to spruce yield decrease. These observations are tentative as such growth predictions are currently not well refined, and even assuming they were accurate, their significance could only be judged in terms of management objectives. The lower spruce stocking and yield results would be unacceptable for softwood oriented management, but may be acceptable for mixed-species management. Even without specific objectives for wildlife habitat (e.g., hiding cover, thermal cover and browse for ungulates) or for landscape

Figure 4
Percent Residual Spruce, 2.5 to 14.0m

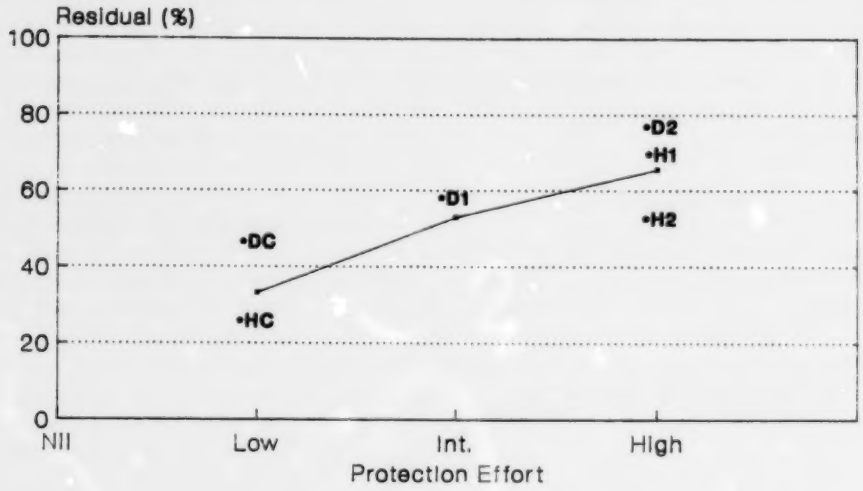


Table 5. Residual Crop by Treatment and Protection Effort (trees 2.5-14.0 m)[1]

Treatment	Stems/ha		Post-cut percent	Protection effort[2]
	Pre harvest	Post harvest		
DC	550	238	43.3	Low
HC	1744	403	23.1	Low
D1	391	209	53.4	Int.
D2	323	233	72.1	High
H1	740	485	65.5	High
H2	1994	1181	59.2	High

[1]Includes undamaged trees and trees with acceptable damage, including broken leader, broken branches, minor bark scrapes and gouges.

[2]Protection effort was subjectively assigned as low, intermediate or high depending upon the combination of planning, layout, supervision and crew experience and attitude in each case.

aesthetics, the treatment results have already been judged by project participants as superior to conventional operations. Such benefits from an understory protection approach to mixedwood management could be more effectively achieved if they were integrated into timber management planning as specific objectives at early planning stages, as recently described by Bonar (1989). Preharvest silviculture prescriptions (PHSP's) as currently required by law in BC would be an important component of this planning process.

SUMMARY AND CONCLUSIONS

1. Mixedwoods are an important regional source of both timber and non-timber resources. There is growing public interest in multiple-use management and increasing criticism of the suitability of current clearcut harvesting practices for that purpose.
2. Stands with white spruce understories are an important component of the mixedwood mosaic, especially in stands inventories H and HS, and current harvesting practices do not provide adequate understory protection.
3. Recent dramatic increases in aspen utilization are resulting in the allocation of large volumes of aspen in stands inventoried H and HS, jeopardizing a significant amount of spruce understory.
4. This report presents a two-stage tending and harvesting model which should facilitate the release of spruce understories during the aspen harvest and promote the subsequent growth of a new aspen sucker stand while the released spruce are maturing. The model should also reduce or avoid the risks and costs of regenerating spruce on mixedwood cutovers, increase the short-term softwood timber supply, and address some of the inadequacies of clearcut harvesting with respect to integrating non-timber objectives into timber management plans and practices.
5. A recent cooperative field project initiated to test the feasibility of adapting available harvesting technology to protecting understory spruce while harvesting aspen has yielded the following preliminary results:
   a) major improvements in the protection of understory white spruce during aspen harvesting are possible using conventional logging equipment like feller-bunchers and grapple skidders in stands up to 1200 understory spruce per ha (exemplified in treatment H1), and using equipment like Swedish shortwood systems in understory densities of 2000/ha or more (exemplified in treatment H2).
   b) the key to success is *protection effort*, regardless of equipment. It includes:
      i) management objectives set for all relevant resource interests at the stand level, including pre-harvest silvicultural prescriptions (PHSP's), supported by an adequate stand inventory which includes the amount and distribution of spruce understory.
      ii) selecting equipment and harvesting patterns to match stand and site conditions, thereby minimizing multiple stand entries for felling and forwarding, which are a significant cause of understory damage.
      iii) pre-planning and pre-locating skid trails, landings and protective features like rub stumps in relation to understory density and distribution.
      iv) adequate crew training and supervision, coordination of operators performing different functions, and the attitude and motivation of operators are critical elements in protection, as well as production.
   c) In feller-buncher/grapple-skidder treatments, mortality was most prominent and was mainly skidder-related. Damage was secondary to mortality and was somewhat greater during felling.
   d) Equipment with directional felling capability and the ability to accumulate trees and place then on skid trails is able to substantially reduce both felling and subsequent skidding damage.
   e) In the Swedish shortwood system, *damage* was most prominent, and occurred mainly during the felling function. Delimbing and bucking functions caused less damage but more mortality than the felling function. The forwarder itself caused minor damage and mortality.
   f) Specialized equipment like the Swedish shortwood processor which work reasonably well in stands with a high density understory should be even better if used in lower density understory stands or in stands where trees to be harvested are of a size which will allow the machine to fell all material in one pass to function without deviating from a relatively straight path - i.e., using full boom capability - and where small crown sizes will help reduce felling damage and mortality. A large single-grip machine would probably function with less damage then the double-grip machine used in this project, under similar stand conditions.
   g) Scattered large spruce are a potential major source of felling and skidding damage in these stands. If they cannot be directionally felled, limbed and

topped and skidded log-length consideration should be given to leaving them to provide additional seed for the next spruce crop if they are windfirm.

h) Acceptable spruce residuals must be defined in management objectives, and equipment, planning, training and supervision adapted accordingly. Many aesthetics and wildlife habitat objectives may be met at considerable lower residual densities (i.e., 200 to 400 per ha) than optimum future spruce yield objectives which require 600 or more trees per hectare at age 40.

i) Harvesting costs, equipment productivity and details of operational procedures for this project have been reported by Sauder and Sinclair (1989) and Brace (1990).

j) There is a need for special operating ground rules with respect to utilization in harvesting operations involving the first entry into previously unmanaged stands. It may be best in the long run to leave individual large-crowned trees and to leave merchantable individual trees uncut in clumps of high-value understory in order to prevent severe damage to the residual stand. There is also a need to accommodate selected high stumps (rub stumps) left for purposes of protection along skid trails, and to reassess slash rules as they may relate to equipment such as short-wood processors.

k) Results of this project will be updated over the next 5 years to show the effects of factors such as blowdown and weevil damage, and to monitor actual growth response of both spruce residuals and aspen suckers.

l) The jury on the feasibility of retaining viable spruce residuals when harvesting overstory hardwood is still out - *but* - there is plenty of evidence in this and other trials that a favorable ruling is possible if both government and industry are *committed* to such work.

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CURRENT INVESTIGATIONS IN SILVICULTURE

WHERE ARE WE NOW AND WHERE DO WE WANT TO GO IN THE FUTURE?

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ABSTRACT

White spruce has been, until very recently, the major commercial species in the Boreal White and Black Spruce Biogeoclimatic Zone. The silviculture research has been therefore focused on regeneration and silviculture of white spruce. Many research projects which have been conducted on white spruce silviculture can be classified under one of the following categories: site preparation (mechanical, chemical, fire, combination), planting stock quality (stock type selection and quality evaluation), studies on competing vegetation (autecology and synecology), plantation maintenance and release (chemical and mechanical), herbicide efficacy studies (which herbicide, when, and what rate), and ecophysiology of white spruce (physiological responses to microclimate changes caused by site preparation and vegetation competition).

As aspen and other hardwoods are gaining commercial importance, the base of silviculture research has to become broader and include silviculture of hardwoods. The specific aspects of mixedwood and aspen silviculture to be addressed by research are: identification of ecosystems most suitable for hardwoods; susceptibility to decay and insects, particularly research on aspen trunk rot (*Phellinus tremulae*); detection of decay; stocking standards; stand tending requirements; growth and yield projections; reforestation requirements for pure aspen and mixedwood types; regeneration response; potential soil compaction and erosion; and identification and promotion of genetically superior aspen clones.

The northern interior of British Columbia has an extensive silviculture research program. The number of silviculture research projects particularly increased since 1985, with the onset of F.R.D.A. Amongst British Columbia's forest regions, the Prince George Forest Region has the largest proportion of backlog NSR, defined as forest land not occupied by commercial species which until very recently were either spruce, pine or balsam. Most of the past and current research program is therefore focused on spruce silviculture and, to a lesser extent, pine.

The best spruce sites are fresh to moist, medium to very rich. Such sites can support not only excellent spruce growth, but also luxurious growth of herbs, shrubs, and formerly non-commercial trees. In addition, spruce is a late succession species, poorly adjusted to full sunlight at early age and growing slowly in comparison to its competitors. The result is vegetation competition and overgrowth of spruce by undesired vegetation. Aspen is one of the species that regenerates and grows rapidly and outgrows spruce.

Large proportions of the past and existing silviculture research have been directed to remedy this situation, namely to find how to establish spruce on clearcuts and how to control competition of undesired vegetation. Research has

studied all potential methods, including: different methods of site preparation to eliminate existing competing vegetation and to reduce rate of establishment and growth of new vegetation; controlled fire; different kinds of mechanical site preparation; site preparation using herbicides; and combinations of some of these methods, such as browning by herbicides with subsequent burning. Studies on use of different selective herbicides to eliminate competing vegetation in spruce plantations is another large research category. Several studies have been conducted on effectiveness of herbicides on particular competing species, and the influences of timing and rate of application.

Research to date has made it clear that a prerequisite of effective vegetation control is thorough understanding of the biology of competing species. Studies on autecology of competing species were conducted. More recently, studies on competing vegetation complexes were initiated.

Successful reforestation depends as much on survival and rapid growth of planted seedlings as on reducing growth of competing vegetation. Research projects evaluating growth of different stock types were conducted. Methods for evaluating seedling physiological status, vigor, and ability to grow rapidly after planting, have been tested. New methods, such as variable chlorophyll fluorescence, have also been developed.

Recent research studies focused on microclimate monitoring after planting, particularly changes in soil temperature and moisture induced by different site preparations. Increased soil temperature resulted in faster seedling growth and more rapid outgrowth of competing vege tation. At the same time, physiological changes in seedlings were monitored. The tentative results of these ecophysiology studies confirmed that spruce at an early age is not adapted to full sunlight and rapid evapotranspiration. Rapid evapotranspiration resulted in excessive water pressure deficit, closure of stomates, and cessation of photosynthesis. Reduction of light intensity by approximately 30 to 35% was recommended, which corresponds to conditions under an open deciduous canopy.

Results of current research on spruce regeneration indicate that to establish a plantation on a large clearcut it is essential to prepare the site to reduce vegetation cover and to increase soil temperature, to use vigorous high quality planting stock, and to control vegetation development after planting (by using herbicides). The only way to reduce "growth check", which is a slowing down of growth after planting, is by reduction or elimination of the water pressure deficit by reducing light intensity and evapotranspiration. It is evident from these requirements that regeneration of spruce on clearcuts is a complex expensive task that is prone to failure.

Aspen, on the other hand, is an early succession species that readily regenerates on open, moist fertile sites after clearcutting or after fire. Aspen requires full light and early growth is rapid. In British Columbia, until recently aspen was considered a weed species because of inferior wood qualities as compared to spruce. However, in Europe and the Soviet Union aspen has been used for decades. In recent years the North American attitude has changed. Aspen is now used for pulp and for "value added" products, such as waferboard. In Minnesota, aspen sawlogs are cut into lumber and used, after special preservative treatment, in house construction. In northeastern British Columbia, the realization that aspen is a valuable resource happened quickly; at present about 1.6 million m^3 is utilized annually by the Louisiana Pacific oriented standboard operation in Dawson Creek.

The change in aspen use and product value brought a need to redesign silviculture research priorities. Land covered by aspen is no longer classified as NSR, and some of the productive forest land may be managed deliberately for aspen rather than spruce. This change brings new research requirements and priorities. The need for new information on hardwood management was reviewed by Peterson et al. (1989). The following discussion focuses mainly on reforestation and silviculture information needs for aspen and mixedwood management.

One of the first decisions to make is which forest sites are best for aspen, spruce, or mixed stands. Refinement of the existing biogeoclimatic ecosystem classification and interpretation of site units for regeneration and productivity are essential prerequisites for optimal use of forest land.

Regeneration of aspen is predominantly by root suckers, which after fire or logging appear in great density and grow rapidly. However, it has been noted that in the Fort Nelson area of British Columbia there is not always vigorous suckering after logging. This could be a result of the naturally cooler soils at that latitude, in combination with the relatively thick forest floor that limits warming of the rooting zone after canopy removal. Such warming is one of the key triggers for sucker formation. The potential unreliability of suckering may make seedling silviculture more important for aspen in the cooler parts of its range than it is further south. More information is needed on the effects of harvest method and harvest timing on suckering density. Site-specific stocking standards for both aspen and mixed stands of aspen and spruce need to be developed.

The concept of aspen as a nurse crop for spruce is often mentioned but the ecological basis for this concept is not well defined. From other regions there is evidence that there is increased weevil damage to conifers after over-

story aspen trees are removed. Aspen is also know to protect understory spruce from late spring frost and from intensive summer sun radiation. For aspen and spruce there is remarkably little information on possible "co-operation" in which both species benefit by the association without the relations being obligatory for survival, or "commensalism" in which one species is benefitted by the association and the other is not affected. Stand-tending practices in mixed stands are not well developed. Guidelines for thinning aspen stands and for spruce release from aspen overstory without causing excessive damage to spruce, although well documented for study sites in Manitoba and Saskatchewan, need to be re-evaluated for sites in northeastern British Columbia. Harvesting of aspen with minimal damage to spruce understory is essential.

A major problem in aspen utilization is decay. At harvesting age, about a quarter of aspen logs are affected by aspen trunk rot (*Phellinus tremulae*). Reduction of decay and timing of harvest before major decay occurs is critical. Trees must be harvested after they are large enough for utilization, but before decay is well advanced. Optimum harvesting age to maximize yield and log quality and to minimize decay defects has to be determined for specific sites.

A considerable amount of information on growth of aspen has been assembled for various locations within its natural geographic range. However, site-specific growth and yield curves for pure aspen stands and for mixed stands need to be developed for northeastern British Columbia.

Effects of different harvesting methods and timing of harvest on soil, particularly soil compaction, erosion, and changes in humus decomposition rate requires additional site-specific information.

Application of genetic principles to management of natural aspen stands is not well developed. It is evident that some aspen clones possess superior growth, and it is suspected that some of these superior clones may be triploids. Fast growing and high quality clones need to be identified, mapped, and marked in the field. Standards for identifying these high quality clones are needed. Methods for promoting fast growing, high quality clones need to be developed.

Besides the required silviculture research there is a need for innovative wood technology developments. There is a large potential for improved aspen wood utilization, for both pulp and lumber. The development of future directions for silviculture research in northeastern British Columbia has to take into account the new perceptions of aspen use. Instead of considering aspen as a weed or as an obstacle to spruce regeneration, aspen is gradually gaining equal status with spruce. For this reason, future research has to be directed toward aspen and mixedwood silviculture, toward developing methods for growth of high-quality aspen stands, and toward growth of mixed stands in which aspen will serve as a nurse species for spruce.

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THE FUTURE FOR MIXEDWOOD MANAGEMENT IN B.C.

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ABSTRACT

In northern British Columbia hardwoods represent a substantial portion of total forest biomass and occupy in excess of 2 million hectares. Integrated resource planning is essential to resolving conflicts and to ensuring that development of the mixedwood forest resource is compatible with a range of resource values. Development of new approaches to integrated resource planning and resolving conflicts is the key to future development of our northern mixedwood forests.

Mixedwood forests of the future will differ substantially from our present stands. In the future, management of mixedwood forests must involve more than just cutting and allowing natural regeneration of hardwoods if we are to meet our timber supply commitments and integrated resource management objectives. Research is required in many areas to support development of management prescriptions, to develop and test alternative approaches to mixedwood management, and development of decision support tools to aid in resolving land-use conflicts.

BRITISH COLUMBIA'S MIXEDWOOD FOREST RESOURCE

British Columbia's hardwood forests represent 3.4% of Canada's total forest biomass and 17% of Canada's total hardwood biomass. Poplars (aspen, balsam poplar and cottonwood) represent approximately 6.4% of the total forest biomass in B.C. while all hardwoods total 8.4% (Bonnor 1985). Much of our poplar biomass is concentrated in northeastern B.C. In the Fort Nelson Timber Supply Area (TSA) 36.9% of net mature volume is hardwoods and in the Fort St. John and Dawson Creek TSA's 21.5 % of net mature volume is hardwoods (Peterson et al. 1989). In these 3 TSA's the gross deciduous land base covers approximately 2 million hectares.

Interest in and utilization of aspen in B.C. has increased rapidly over the past few years. In the future we can expect further increases in utilization of aspen and hardwoods in response to: increasing world fibre demands; technological developments which improve our ability to utilize hardwoods; public interest in the use and management of forest resources; and, costs, problems, and controversy associated with conversion of hardwood forests to coniferous forests.

NORTHERN MIXEDWOOD MANAGEMENT ISSUES

Utilization of hardwoods provides new opportunities for employment and industrial development in northern B.C. However, increased utilization of this forest resource will create increased pressure on deciduous and mixedwood stands in northeastern B.C. with the likelihood of increasing conflicts with other resource users.

Resources in our Northern Mixedwood forests include: Agriculture (Range); Energy; Minerals; Fisheries; Forestry; Heritage and Cultural; Recreation; Water; and Wildlife. Resolving land-use conflicts is a priority issue in the management of northern hardwood and mixedwood forests (Petersen et al. 1989). In many places multiple tenures already exist, for example in some areas grazing permits, guide and outfitters licences, and pulpwood agreements share the same area.

Achieving integrated resource management in our mixedwood forests requires a systematic approach. The B.C. Forest Service is working with other agencies to develop an integrated resource planning system to assist in resolving conflicts and in developing long-term integrated resource management plans for managing forest areas.

With appropriate management we can enhance the diversity and value of our hardwood and mixedwood forests. Young aspen stands provide a valuable food resource for moose, deer, and hares and provide cover for small mammals and songbirds. Young and mature forest stands provide cover and shelter for wildlife. Cattle can graze in young aspen stands.

Effective management will involve developing site specific management prescriptions and plans which consider stand level and forest level management objectives and which include: species selection, site preparation, brushing, and stand tending practices. At present we manage stands based on their composition prior to harvest, working towards maintaining leading coniferous and leading deciduous stands. In the future, good management practices will require that we manage for hardwoods as well as softwoods on a site specific basis.

We must ensure that our move into mixedwood management is indeed one involving conscious decisions and not one of accepting what we get by default. As Drew (1988) suggests for Alberta, a laissez faire attitude to mixedwood management - "regenerate extensively and live with what you get" - will result in future forests which will be less suited to meeting either sustained yield or multiple use objectives.

Refined tools are needed to assist in selecting appropriate treatment and management options. The Ecosystems approach provides a useful basis for making ecologically sound, site specific decisions.

A recent field guide for seral aspen ecosystems of one variant of the Boreal White and Black Spruce Zone (BWBSc1) (DeLong 1988) includes reference to suitability of sites for hardwoods, softwoods, agriculture, and range uses. Costs, desired products, local wood supply commitments, and other resource values must also be considered in selecting a management approach. Because of the number of factors which must be considered and the interaction between factors, future decision support tools will likely rely heavily on emerging computer technology, particularly simulation models and geographic information systems (GIS). The ecosystems approach provides a good foundation for this work.

Opportunities for mixedwood management at the stand and at the forest level have yet to be fully explored. At the stand level a deciduous component may improve nutrient availability, increase forage availability for wildlife and cattle, and provide a nurse crop to reduce frost damage to conifers. However, too much deciduous cover will reduce conifer yields.

We need to try new approaches in managing mixedwood stands. Practices such as managing spruce regeneration in the understory of aspen stands (Brace and Bella 1988) may be useful in areas where frost or competing vegetation create problems for regenerating white spruce.

At the forest level we must be concerned with supply commitments and with integrated resource management objectives. Using integrated resource planning we can work towards creating a mix of stand age classes and composition within individual watersheds or forests to maintain or enhance wildlife habitat while reserving key areas such as critical winter habitat.

THE FUTURE

Achieving effective management of our mixedwood resource requires planning activities at the stand, forest, watershed, TSA, Region, and Provincial levels. A substantial body of information and advanced decision making tools are needed to assist resource managers. Further technological developments are needed in harvesting and processing to increase utilization of aspen in B.C.

At present the B.C. Forest Service is acquiring much needed information and is working on approaches to assist in management decision making. We are firmly committed to the wise integrated management of our northern mixedwood resources. Much of the current hardwood AAC of nearly 2 million m^3/yr which covers 950,00 ha in the Dawson Creek and Fort St. John TSA's is committed or soon will be. In addition, private land holdings will become increasingly important in the development and management of northern mixedwood forests.

We expect that future hardwood stands will differ substantially from present, mature stands. We are planning to harvest our current deciduous stands to create an age class distribution which will maintain or improve yields. In the Dawson Creek TSA initial harvest of older age classes of aspen will be accelerated to levels above long range sustained yield (LRSY) levels to permit use of these stands before their value declines further and to create new stands where decay and stain problems will be substantially reduced (Figure 1). In contrast, in the Fort St. John TSA the inventory is younger and utilization will start at LRSY levels.

Increasing utilization of the mixedwood resource is providing new economic opportunities in northern B.C. In addition, it provides an opportunity for the forestry community to look at new approaches to integrated resource

management planning while ensuring the sustainable development of our northern mixedwood forests.

CONCLUSIONS

Our northern mixedwood forests are a valuable resource. Strategic planning is required to ensure effective management and sustainable development of our mixedwood forests. Our management of northern mixedwood forests must consider wildlife, agriculture, recreation, forestry, and other resource values and must be directed towards achieving integrated management while meeting timber supply commitments.

Management of mixedwood forests must involve more than just cutting and allowing natural regeneration of hardwoods. We must make conscious decisions for the regeneration and silviculture of coniferous, deciduous, and mixedwood stands if we are to achieve our integrated resource management objectives. We must work together in developing solutions to key problems and issues in the management of our mixedwood resources.

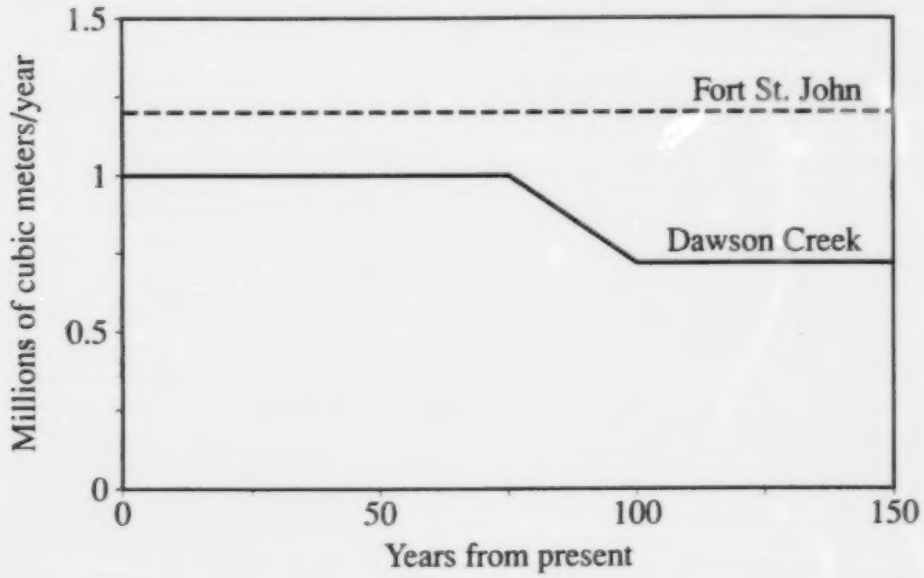

Figure 1. Deciduous harvest forecast for the Dawson Creek and Fort St. John TSA's.

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CLOSING REMARKS BY KEN W. PENDERGAST,

Chairman Northern Mixedwoood '89
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Ladies and gentlemen, we have concluded the technical session for this Northern Mixedwood '89 Symposium.

The objective of the Steering Committee was to have speakers present technical papers to reflect the current knowledge and experience available in Europe and North America pertaining to mixedwood management. Topics covered in day one were:

- World market conditions
- Mixedwood management decisions pertaining to:

  - Inventory
  - Ecology
  - Regeneration
  - Harvesting technology
  - Pest management
  - Integrated use
  - Economics

Today, we have had an opportunity to hear from our Soviet and Scandinavian friends, the challenges they face in harvesting mixedwood due to social and economic trends, utilization and market demands. As such, we have learned there are wide parameters in both utilization and hauling distances dependent on economic needs.

This afternoon was dedicated to research and silvicultural enhancements and future needs to cope with mixedwood management. The future of mixedwood management in British Columbia has been summed up by our Chief Forester, indicating that with the new markets and interest in our forests, the opportunity for industry is very strong and forest managers have to remain proactive to remain competitive.

I believe all speakers are to be commended on their talks. The information was presented in a format useful to forest managers. Those practitioners can now take the information received over these past two days and apply the experience and research to their forest areas.

However, we must recognize that our objectives were intentionally ambitious, and that we have a long way to go in securing the total answers to mixedwood management. We have uncovered the tip of the iceberg, and only continued experimenting and associated research will provide the answers to the many questions in our minds. Our Minister of Forests indicated during his talk, the opporunity for future symposia of this nature, to assist in this regard.

As Chairman of the symposium, I want to thank all the speakers for their excellent presentations. I would like to also thank each and everyone of you people for attending and making our symposium in Fort St. John the success that we feel it is. I look forward to participating in another Mixedwood Symposium in a couple of years, after we have had the opportunity to broaden our experience base through the information and research initiatives.

We have good participation planned for the field day tomorrow in both the Dawson Creek and Fort St. John Forest Districts' Demonstration Forests. The team approach to evaluating these sites with the expertise at hand is sure to present some valuable pre and post harvest prescriptions that can be considered for our local forest management decisions.

I wish everyone a prosperous year and a safe journey home. Thank you. Have a great day.

APPENDIX I

SUMMARY OF COMMENTS, SUGGESTIONS AND CONCERNS AS A RESULT OF THE NORTHERN MIXEDWOOD '89 FIELD DAY

APPENDIX I

SUMMARY OF COMMENTS, SUGGESTIONS AND CONCERNS AS A RESULT OF THE NORTHERN MIXEDWOOD '89 FIELD DAY

COMPILED BY

MICHAEL C. PEDERSON

1. Timber Supply Area objectives are required to determine:
   - what level of coniferous AAC is to be maintained.
   - what will be the impact on both the coniferous and deciduous AAC's if we are not managing for either pure spruce or pure deciduous types.
   - what it is exactly that we want to grow on our mixedwood sites.

2. An overall management strategy should be developed concentrating on coniferous - deciduous management conflicts before extensive logging in the mixedwood types occurs.

3. An updated and accurate inventory is essential to make intelligent management decisions. The method of assessing the inventory should be sensitive enough to detect spruce understory under aspen and differentiate between aspen and balsam poplar.
   - the present inventory indicates aspen as the leading species in types where spruce is *now* the leading species. Are aspen LRSY's overestimated?
   - balsam poplar stands labeled as aspen will impact on the type of deciduous manufacturing facilities required.

4. Growth and yield information in the Peace River area on conifers, deciduous and mixedwood is poor. This situation must be improved upon before the AAC is fully committed.

5. A stand should be managed for either coniferous sawlogs or deciduous fiber, but not for both at the same time, following harvest.
   - there is a high cost associated with harvesting aspen while protecting the spruce understory (made up of both spruce mortality due to logging damage and the added cost of maneuvering fallen aspen to protect the spruce).
   - 2 or 3 species with different rotation lengths within the same stand represents a cost that would be greater than any benefits arising from the practice.

6. All sites visited had options for either coniferous, deciduous or mixedwood management. The choice of options varied on:
   - personal viewpoints.
   - timber supply requirements.

7. The British Columbia Biogeoclimatic Ecological Classification System may not, in its present form, be a useful tool to predict mixedwood productivity. On the tour, all sites were zonal with a range of poor to average for predicted aspen productivity.

8. More research needs to be funded into mixedwood logging, of natural mixedwood stands, to minimize understory damage.

9. Attempts should be made to create better wildlife and aesthetic conditions by utilizing smaller cut block sizes. These smaller cutblocks should offer a diversity of cover, if they are a mixture of deciduous and coniferous blocks.

10. Will the provincial government allow reduced stumpage in a selectively logged area, or under a two-pass system for aspen and spruce?
    - this would work if the licensee had a fully integrated operation.
    - separate licensee's with overlapping tenures (i.e. one coniferous and one deciduous) would usually not look after each other's interests.

APPENDIX II

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